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PRINCIPLES OF

COST-BENEFIT ANALYSIS FOR ERTS EXPERIMENTS

VOLUME I

Prepared for

The National Aeronautics and Space Administration
Office of Applications

by

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PREFACE

Volume I can be used internally by NASA and externally by researchers to gain an understanding of the techniques and terms in cost-benefit analysis.

Volumes I and II, taken together provide an outline of the cost-benefit procedure and the theoretical foundation for those who must do an actual cost-benefit study. Volume II contains a hypothetical example of a cost-benefit study.

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Chapter 1. INTRODUCTION

1.1 Basic Elements of A Cost-Benefit Study

The basic elements which should ideally be included in the cost-benefit study are:

1. A definition of the objective to be accomplished in the ERTS application.

2. Specification of all relevant assumptions under which the study will be conducted.

3. Enumeration of all reasonable alternatives by which the objective may be accomplished.

4. Calculation for each alternative of the benefits derived and the costs incurred during the undertaking to determine the efficiency of each alternative.

5. Enumeration and, where possible, quantification of non-efficiency considerations associated with each alternative.

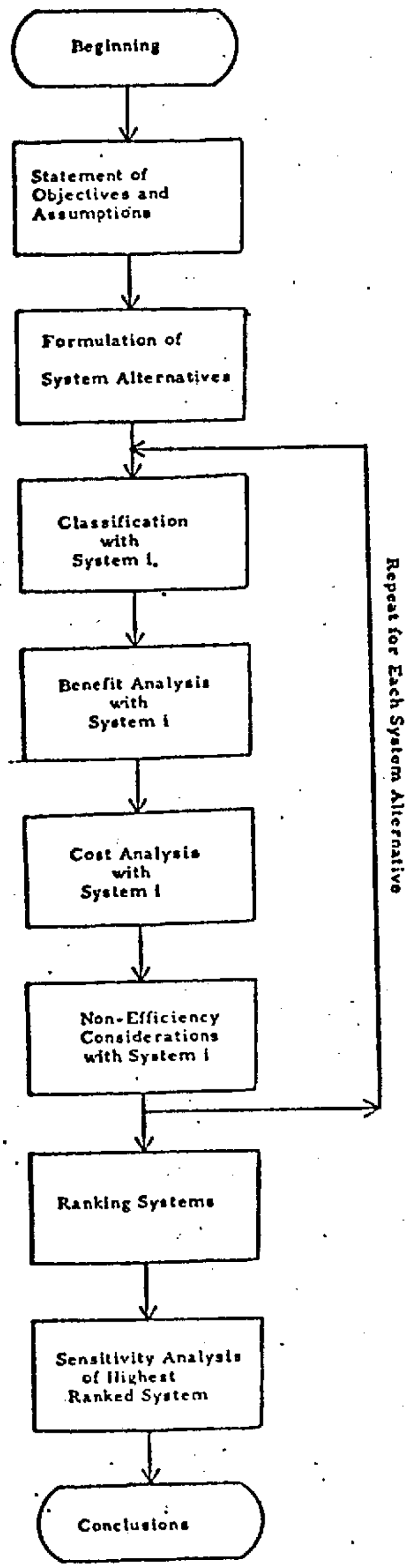
6. Ranking of the system alternatives on the basis of both efficiency and non-efficiency considerations.

These steps are depicted in Figure 1.

1.2 Special Considerations for ERTS Experiments

A distinguishing feature of ERTS experiments is the difficulty of measuring benefits which are often in the form of externalities (see Appendix II, Section E for a discussion of externalities), non-marketable benefits. Therefore, it is usually necessary to take an "unequal cost/ equal benefit" approach. However, considerable space in this paper

Figure 1


Beginning
Statement of Objectives and Assumptions
Formulation of System Alternatives
Classification with System i
Benefit Analysis with System i
Cost Analysis with System i
Non-Efficiency Considerations with System i
Repeat for Each System Alternative
Ranking Systems
Sensitivity Analysis of Highest Ranked System
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is devoted to suggesting approaches to the measurement of benefits. Some progress can be made with conventional analysis, some state-of-the-art techniques, and some ingenuity. This emphasis on benefits distinguishes this manual from similar manuals [59, 61] in other government agencies which emphasize cost considerations.

Another consideration in an ERTS experiment cost-benefit analysis is the credibility of the estimates. Since many experiments are being evaluated simultaneously it is possible to compare the value of experiments. But only if the assumptions behind the estimates, the source of the estimates, and the technique of calculation and classification are clearly specified can these estimates be evaluated and compared.

This paper seeks to provide a sound analytic framework for experimenters and a basis from which the credibility of the cost and benefit estimates can be imputed.

Lack of credibility in benefit and cost estimates often in the past has stemmed from unrealistic consideration of system alternatives and from failure to distinguish between actual and potential benefits of an ERTS experiment. It is important for a sound economic analysis that all reasonable alternatives are specified. Combinations of any of three tiers (ground, aircraft, and satellite) of information gathering may be reasonable alternatives. The following four concepts are offered as both an example and actual group of feasible system alternatives:

1. Ground inspection
2. Satellite and ground inspection
3. Aircraft and ground inspection
4. Satellite, aircraft, and ground inspection

As regards the difference between actual and potential figures it will be urged that, for those benefit estimates for which this is a consideration, the estimating model explicitly considers the ratio of actual to potential benefit and this ratio be part of the overall parametric analysis. The general cost-benefit model would thus be:

$$NPV = \sum_{t=1}^{N} \frac{B_t (R_t) - C_t}{(1 + \gamma)^t}$$

where

NPV - net present value

N - planning horizon

R - ratio of actual to potential benefit

B - benefit

C - cost

γ - social rate of discount

t - year of project

1.3 Depth of the Analysis

Not all of the techniques discussed below need be or should be a part of any economic analysis of an ERTS experiment. The depth of the analysis should depend on the scope and significance of the experiment, the technical and financial assistance available, and the judgment of the experimenter. While the analyses described in this paper cover a broad range they are not definitive and should certainly be supplemented when appropriate.

Chapter 2. COST-BENEFIT ANALYSIS

A complete economic analysis to accompany an ERTS experiment should contain the following elements: statement of objective, specification of assumptions, enumeration of system alternatives, proper classification, benefit analysis, cost analysis, non-efficiency considerations, and final system selection.

2.1 Statement of Objective

The goal to be achieved by the experiment must be clearly stated. The statement should specify who will use the information collected, how it will be used and for what purpose it will be used.

2.2 Specification of Assumptions

The analyst should state all relevant assumptions on which the study is based.

2.3 Enumeration of System Alternatives

The enumeration should be exhaustive if possible of all reasonable alternatives for gathering the desired information and it should also indicate the criteria which will be employed to rank the different systems.

2.3.1 All Reasonable Alternatives

Experimenters should consider the desired information as available from a three tier system. The three tiers are ground, high-altitude aircraft, and satellite. Individual elements or combinations of elements of the three tiers may provide the basis of an alternative.

The following four alternatives are given as a plausible example:

1. Ground inspection
2. Satellite and ground inspection
3. Aircraft and ground inspection
4. Satellite, aircraft, and ground inspection.

2.3.2 Efficiency Criteria for Selecting Among Alternatives

Efficiency considerations, or primary effects, refer to the labor and capital resources absorbed and the final demand (as defined in Section 2.6) met by a given ERTS application.

There are, in general, three classes of criteria which the analyst may employ when comparing "two or more" alternatives. They all belong to the general category of cost effectiveness analysis. Cost effectiveness analysis may be compared to cost benefit analysis which is the process of assessing whether the benefits of a "single" option are worth the costs.

a. Unequal cost/equal benefit analysis. We may define the alternative systems such that they all provide equal capability (benefits). It is then possible to rank them on the basis of the present value of their life cycle costs.

b. Equal cost/unequal benefit analysis. We may allocate equal budgets (cost) to each alternative and rank them on the basis of their technical capabilities or the present value of their benefits within the planning horizon.

c. Unequal cost/unequal benefit analysis. We may rank the systems on the basis of the ratio of their costs and benefits. This criterion is least desirable since any interpretation of the ratio would be ambiguous.

For a rigorous discussion of these criteria see Appendix II, Section D.

2.3.3 Non-Efficiency Criteria (Secondary Effects)

The term secondary effects as used in cost-benefit literature is taken to include all effects outside of efficiency considerations. Each alternative should be evaluated on the basis of secondary effects where possible. Where differences arise among systems in their secondary effects the analyst should rank the systems using these effects as criteria.

Unfortunately the powerful tools developed by the economist for efficiency considerations often cannot be employed to evaluate secondary effects. A qualitative ranking is usually possible and is the minimum which should be provided. The more important secondary effects are:

a. Income distribution effects. These are shifts in the relative income flows of various sectors of the economy independent of the total level of flows. Does information from the experiment cause the incomes of one sector to rise at the expense of another sector? How does this affect the equality of income distribution?

b. International effects. In particular what will be the economic impact on the United States of use of data by foreign countries? And what will be the impact on U.S. foreign trade and balance of payments?

c. Environmental effects. Efforts of this task should include:

(1) Identification of potential ERS data impact on the protection and maintenance of environmental quality;

(2) Evaluation of benefits in terms of desirable environmental goals (preservation of open spaces, control of pollution, prevention of erosion, etc.);

(3) Evaluation of costs of the alternative systems as applied to environmental problems, and

(4) Analyses of environmental impacts in accordance with the Council on Environmental Quality guidelines which require a description of the proposed project or action, evaluation of probable impact on the environment (primary and secondary effects), adverse effects which cannot be avoided, alternatives, the relationship between short term and long term effects (including cumulative effects), and irreversible or irretrievable commitment of resources.

d. Social effects. The social analysis should be concerned with:

(1) Applying methodology described to social analysis to identify potential ERS data consequences for persons or groups. Consider implications for health and life, provision of educational, scientific and cultural opportunities, amelioration of effects of disaster and for national security.

(2) Evaluating benefits (contributions) resulting from ERS data as it influences employment, and population and the quality of life for affected populations. The measures used to describe these benefits may vary but, when possible, should be in dollars, other quantitative units or qualitative terms. Employment effects should be specified by income level and job category and include impacts on minority groups in U. S.

(3) Evaluating costs such as potentially adverse effects on persons or groups resulting from operation of an ERS system or from distribution of data.

Consideration of the secondary effects when they are not expected to differ from alternative to alternative may be removed for the iteration and performed after efficiency ranking of the alternatives.

2.4 Classification

The economic analysis should clearly define the users (as opposed to the ultimate beneficiaries) of the data, the geographic area where the benefits are obtained and the costs incurred, and the political boundaries in which the costs and benefits apply. The classification necessary for experiments may differ but in general they should include:

1. Users
2. Geographic area
3. Political division
4. Beneficiaries

2.5 Technical Considerations

The benefits and costs must be estimated in a sound analytical framework. The center of this framework should be the mathematical model with proper consideration given to uncertainty of the model inputs and the time dimension in which the model is being considered.

2.5.1 Modeling

The general form of the model relating benefits and costs is

$$NPV = \sum_{t=0}^{N} \frac{B_t(R_t) - C_t}{(1 + \gamma)^t}$$

with the elements of the model as defined in the introduction.

The analyst must clearly present the specific form of the model. The model should distinguish in the inputs between government activity and private activity. It should also represent the level of activity with which the data is collected and the actual benefits realized should be expressed relative to the potential benefit.

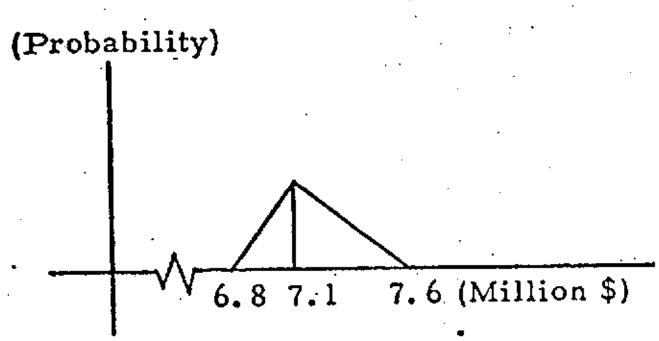
A slightly expanded general model would then be:

$$NPV = \sum_{t=1}^{N} \overbrace{\left[\frac{B_t\,(R_t, A_t) - C_t\,(A_t)}{(1+\gamma)^t}\right]}^{\text{Government activity}} + \overbrace{\left[\frac{B_t\,(R_t, A_t) - C_t\,(A_t)}{(1+\gamma)^t}\right]}^{\text{Private activity}}$$

where A_t = Activity level in period t.

2.5.2 Uncertainty and Cost-Benefit Estimates

Estimates for ERTS experiments cannot be made with certainty. Therefore we should not use deterministic modeling, i.e., we should not feed in single value inputs. Rather, the inputs should be fed in as ranges with a probability associated with each value in the range. For example, in three years from now the price of a particular high-altitude aircraft may be anywhere in the range from 6.8 to 7.6 million dollars with the most likely figure 7.1 million dollars.



Feeding the inputs in as <u>probability distribution functions</u> (PDF) whose shapes reflect the uncertainty associated with each input means the output estimate will be generated as a PDF.

a. <u>Probability</u>. Knowing the PDF surrounding output estimates enables the analyst to quantify the uncertainty of his estimates. It also enables him to quantify the uncertainty associated with decisions based on his estimates. An example of quantifying the uncertainty associated with a decision is given at the end of section C in Appendix II. While PDFs are sometimes given with estimates, quantification of decision uncertainties is rarely done although it is a simple extension and a useful technique for the decision maker. Therefore, the uncertainty associated with decisions in selecting among system alternatives should be quantified where possible.

b. <u>Risk analysis</u>. The most commonly used technique for generating PDFs is the form of risk analysis known as Monte Carlo simulation. A detailed discussion of risk analysis is given in section C in Appendix II.

c. <u>Sensitivity analysis.</u> Sensitivity analysis seeks to answer a specific question of uncertainty - to changes in which of the inputs is the output estimate most sensitive. This is found by perturbing each of the inputs, one by one, from its most likely value and observing the resulting impact on the estimates and decisions. The perturbation may be by:

(1) Equal absolute amounts

(2) Equal relative amounts

(3) Equally likely amounts (when combined with input PDFs)

Sensitivity analysis indicates which input factors are most important to the decision to be made and where the greatest effort should be expended in collecting more input data.

2.5.3 Time and Cost-Benefit Estimates

Time makes its impact on the value yardstick of money through inflation, by the selection of project life, by society's preferences for present consumption as opposed to future consumption, and by new opportunities and situations developing within the project's life.

a. Constant dollars vs. current dollar. All inputs and estimates should be done in constant dollars, i.e., deflated dollars.

b. The planning horizon. The selection of a planning horizon can be critical to determining the economic worth of a project and care should be taken in selecting it. A full discussion of the planning horizon is given in section A, Appendix II.

c. Discounting and present value. A dollar spent today is not the same as a dollar spent three years hence nor is a dollar spent three years hence the same as a dollar spent six years hence. This is because present consumption is more desirable then postponed consumption. Therefore, in order to compare the different cash flows over time for the alternatives being considered it is necessary to discount future cash flows into a common denominator -- their present value.

d. Dynamic costing. When it is foreseen that new opportunities may present themselves during the life of a project there are two methods for handling this situation. The usual method is to have two alternatives, one in which the possibility becomes a reality and the other in which it fails to become a reality. The full net present value calculation is done for both possibilities.

The second method, known as the dynamic costing method explicitly incorporates the uncertainty of a future development into the net present value model. The arrival of new opportunities is viewed as a Markov process and optimal decision strategies can be developed. While dynamic costing is still a state-of-the-art development it may be considered for those experiments where future technical developments will have a major impact. For a rigorous discussion of this method see [19] and [55] .

2.6 Benefits

The benefits from an ERTS information application will be equal to the "final demand" for public and private goods and services which are met. Final demand refers to the desire for products as an end in themselves. Final demand is also known as direct demand. These products may be compared to products desired because they help produce products desired for themselves. These intermediate products meet derived demand. An example of final demand is the sale of an automobile to a consumer by General Motors. An example of derived demand is the sale of machinery by a manufacturer to General Motors.

It is first necessary to list all the benefits (final demand) of the specific application, quantify them for each year of the project, reduce all figures to their present values, and repeat this process for all alternatives.

2.6.1 Several Approaches

It is necessary to use several analytic techniques when attempting to quantify benefits. This is because the value of publicly consumed goods, which are frequently provided free or at nominal cost, is not as easy to ascertain as the value of privately consumed goods. The two general techniques employed are cost effectiveness analysis and supply and demand analysis. Besides the discussion in Section 2.6.3 in this volume, these techniques are discussed rigorously in Section D, Appendix II.

2.6.2 Listing Benefits

The first step in benefit analysis is a complete listing of all benefits. They should be cross classified as public or private, domestic or international, quantifiable or non-quantifiable, and as efficiency or non-efficiency consideration. A form for this listing is offered in Appendix IV.

a. Efficiency considerations. An attempt must be made to quantify all efficiency considerations, i. e., those which impact on the level of final demand.

(1) Public. Publically offered goods and services must be separated from privately offered goods and services. An example of a public service is the water resource management function of the government.

(2) Private. This area encompasses all final goods and services offered in the private market place.

(3) Actual benefits vs. potential benefits. The actual effect on final demand may be considerably below its potential, it may approach its potential as the particular application is better utilized, it may drop away from its potential as substitutes appear in the future. Explicit consideration should be taken of these cases by the analyst. The technique of learning curves (change in time) may be applied on the benefit side similar to the way it is applied on the cost side. Instead of decreasing costs as we "learn" to operate more efficiently, we "learn" to reap more of the potential benefits. See [26].

b. Non-efficiency considerations. An attempt should be made to quantify non-efficiency considerations where possible. These include all effects other than the impact on the level of final goods and services. These are the so-called secondary effects some of which were discussed above.

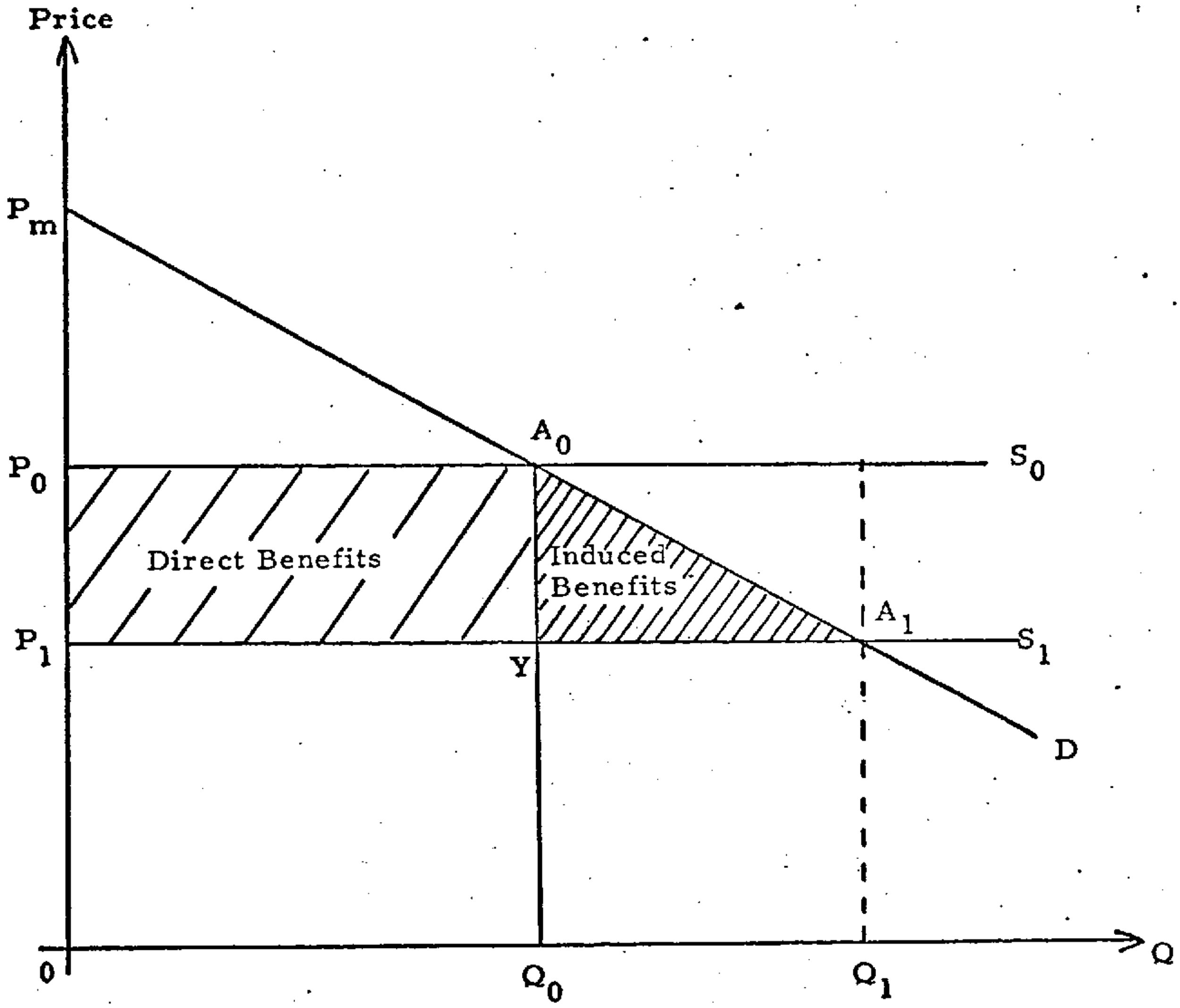
2.6.3 Measuring Benefits

Supply and demand analysis offers a method for measuring the impact on final demand of the private sector and to a limited extend for the public sector. Benefits should be quantified over the life of the project and discounted to present values. In measuring benefits it is most desirable to use parametric methods for reasons discussed in the section on uncertainty.

a. Probability distributions. It is improbable that benefits accuring from an ERTS application can be treated as "known". Estimates must be made with uncertain inputs. These inputs should be entered as probability distribution functions.

b. Demand analysis; price considerations. Cost analysis is usually straight forward and enables us to handle supply shifts. But demand analysis is more complex. Therefore, this section on demand analysis is more rigorous than the rest of Volume I.

Theoretically we can measure the benefits to society of an ERTS application as follows. If the ERTS information enables producers to supply quantities of a given product more cheaply we will have a downward shift in the supply function of this product. This is represented in the following diagram as a shift from S_0 to S_1:



Initially at price P_0 the consumer had a surplus equal to the area $P_0P_mA_0$. This is the consumer's surplus because it represents the extra value consumers are willing to sacrifice rather than do without a given good.

Alternatively, consumers were willing to pay $OP_mA_0Q_0$ but they only had to pay $OP_0A_0Q_0$ which left them with a net benefit (surplus) of $P_0P_mA_0$.

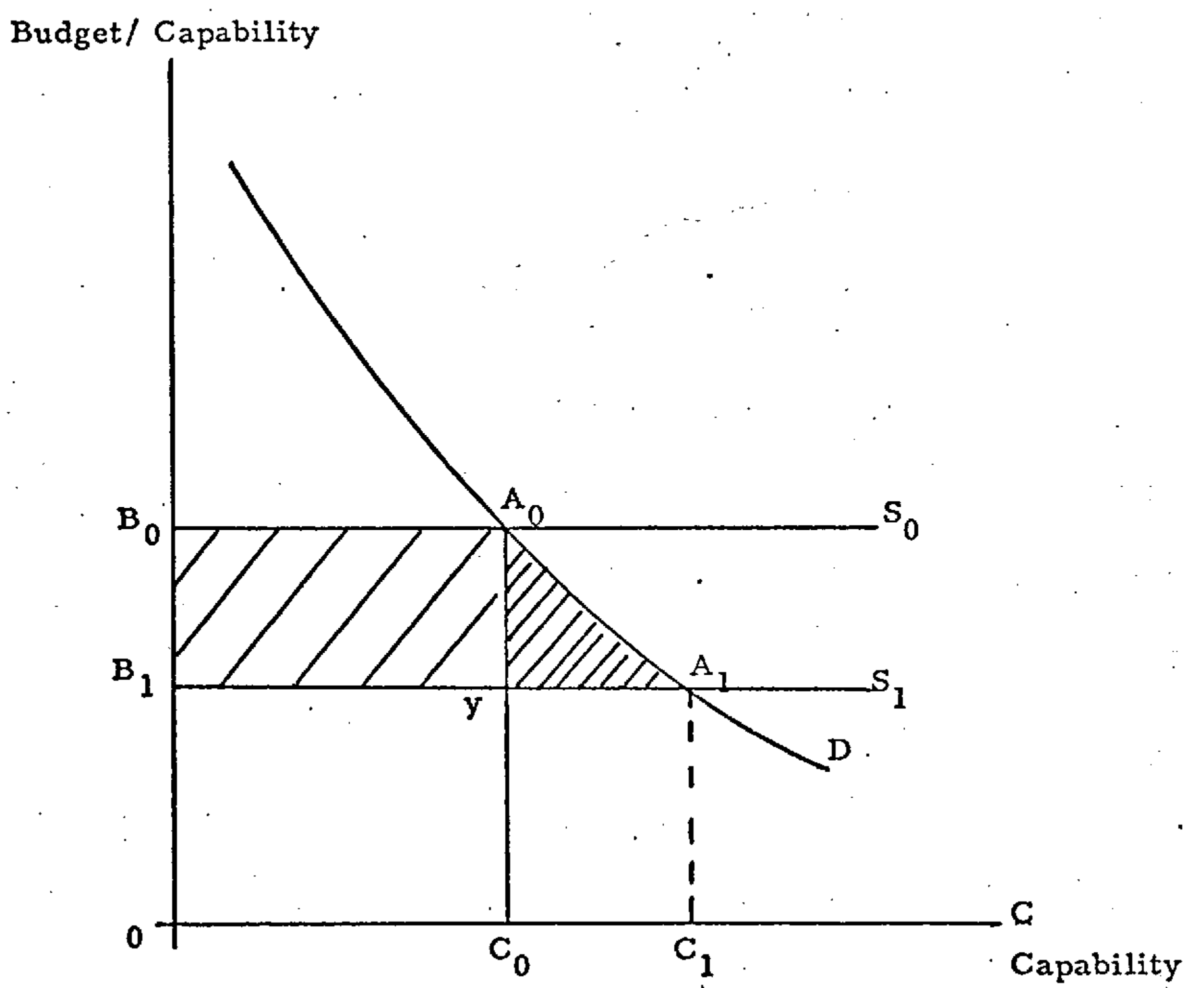
After the shift to S_1 the consumers' surplus or net benefit increases to $P_1P_mA_1$. In other words, the net benefit has increased by $P_1P_0A_0A_1$. This area, $P_1P_0A_0A_1$, represents the value of the ERTS information benefit.

There is extensive econometric literature on estimating such supply and demand functions. Once the supply and demand functions and the shift in the supply curve are known the benefit (increase in consumers' surplus) may be calculated.

Further, the increased net benefit may be broken down into two types. There is a <u>direct benefit</u> equal to $P_1P_0A_0Y$ because the quantity OQ_0 which sold for OP_0 before now sells for OP_1. There is also an <u>induced benefit</u> equal to YA_0A_1 which accrues to the consumers who were "induced" by the lower price to buy the product.

While this technique is acceptable for measuring the benefit from private activity, it is not applicable directly to government activity which frequently renders goods and services free of charge or at a nominal rate. However, cost-effectiveness provides a rough solution to this problem through the equal capability approach and the equal budget approach.

If we re-label the axis on our supply and demand diagram from (price) and (quantity) to (budget/capability) and (capability) we have



The benefit provided by the government is equal to $B_1B_0A_0A_1$. To estimate this area we first assume equal capability (C_0) and compare the budget with (B_1) and without (B_0) ERTS information. The area $B_0B_1A_0Y$ is the direct benefit from ERTS in that it enables the government to provide the same goods or service at a lower budget outlay. To get the area YA_0A_1 we need to know the shape of the demand curve. The usual procedure is to assume unitary elasticity (a given percentage increase in capability generates a similar percentage decrease in budget). We then assume equal budget (B_1) but an increase in capability from C_0 to C_1. We are then able to calculate YA_0A_1. The total benefit from government activity is

$$B_1B_0A_0A_1 = B_1B_0A_0Y + YA_0A_1.$$

The above analysis cannot generally apply when a totally new product or service is produced by ERTS because the demand function cannot be obtained. If the new product, however, has the same attributes as some already existing p roduct, extrapolation of demand may be possible by the abstract commodity approach. An example of an abstract commodity is "transportation." Its attributes are cost and time. The supersonic transport jets are a new product but offering the same abstract commodity, transportation, as regular jets but with different attributes of time and cost. From these attributes the demand for transporation on supersonic jets may be extrapolated.

While this is still a state-of-the art technique some progress has been made. See [2].

c. Definition of benefits. Benefits may be defined as:

(1) The increase in consumer surplus due to meeting direct demand at a lower price.

(2) The increase in consumer surplus due to meeting derived demand at a lower price (This is actually a cost reduction.)

(3) A cost reduction.

d. Externalities; Non-price considerations. Externalities are non-marketable benefits (or costs). These usually require government intervention since the natural play of market forces exerts no control on them. See section E, Appendix II.

e. Selecting a discount rate. The selection of a discount rate is a critical choice and a full discussion can be found in section B of Appendix II.

In general the discount rate should reflect society's marginal social preference for present consumption over future consumption. It is also useful for purposes of comparison that analyses use the same discount rate. With these two facts in mind, the executive office of the president recommends that a 10% discount rate be used [58]. The impact of using other rates such as 5% and 15% should be tested where possible.

There is also some confusion as to when discounting should begin.

1. If the outlays and benefits are realized in lump sum at the beginning of each year, discounting should begin with the second year (first discount factor is 0.909).
2. If the outlays and benefits are realized in lump sum at the end of each year discounting should begin with the first year (first discount factor is 0.909).
3. If the outlays and benefits are realized in a steady stream (the usual case) over each year, discounting should begin with the first year (first discount factor is 0.954).

Discount factors for the 10% discount rate are given in Appendix III.

2.7 Costs

2.7.1 General Considerations

Costs of a particular application should reflect the true opportunity foregone by society. Costs should only be incremental costs, i.e., the extra costs incurred that would not have been incurred if the application were not taken. Therefore, this excludes all sunk costs since they are costs which will not be incurred in the "future" of each investment alternative. Costs of government activity should be distinguished from costs of private activity. Costs should be entered as probability distributions reflecting the uncertainty surrounding them.

a. Opportunity costs. Opportunity costs are the true foregone alternatives of society in undertaking a project.

b. Shadow prices vs. market prices. Market prices generally are the best indication of opportunity cost. Market prices may fail to indicate the true opportunities lost to society by a given investment, for example, if there are price controls on goods and services purchased during the life of the project or the domestic currency is overvalued/undervalued and some of the outlays are for goods and services supplied by foreign sources. In these cases "shadow prices" should be used. Shadow prices are a specific example of opportunity costs which arise as the solution to particular pricing techniques. For a general discussion of shadow prices in cost-benefit analysis see [14].

2.7.2 Life Cycle Costing

All costs should be specified for each year of the life of the project. Examples of forms which might be useful in a life cycle costing effort are presented in Appendix III. Detailed listing of items in a Life Cycle Costing Effort may be got from [62] .

a. Non-recurring costs. Non-recurring expenses include all one time expenditures for research, development, testing, evaluation and investment for the application.

(1) RDT&E.

(2) Investment.

b. Recurring costs. Recurring costs include all personnel and non-personnel outlays involved in the operation of the application.

(1) Personnel costs.

(2) Non-personnel costs.

c. Productivity measurement. Results should be presented as averages as well as totals where possible. This will be useful as a productivity measure over the life of the project and for purposes of interproject comparison.

2.8 Measurement of Non-Efficiency Considerations

The same principles of evaluation, time and classification which apply to the efficiency considerations should be observed for those cases when non-efficiency considerations are classified.

2.9 System Selection

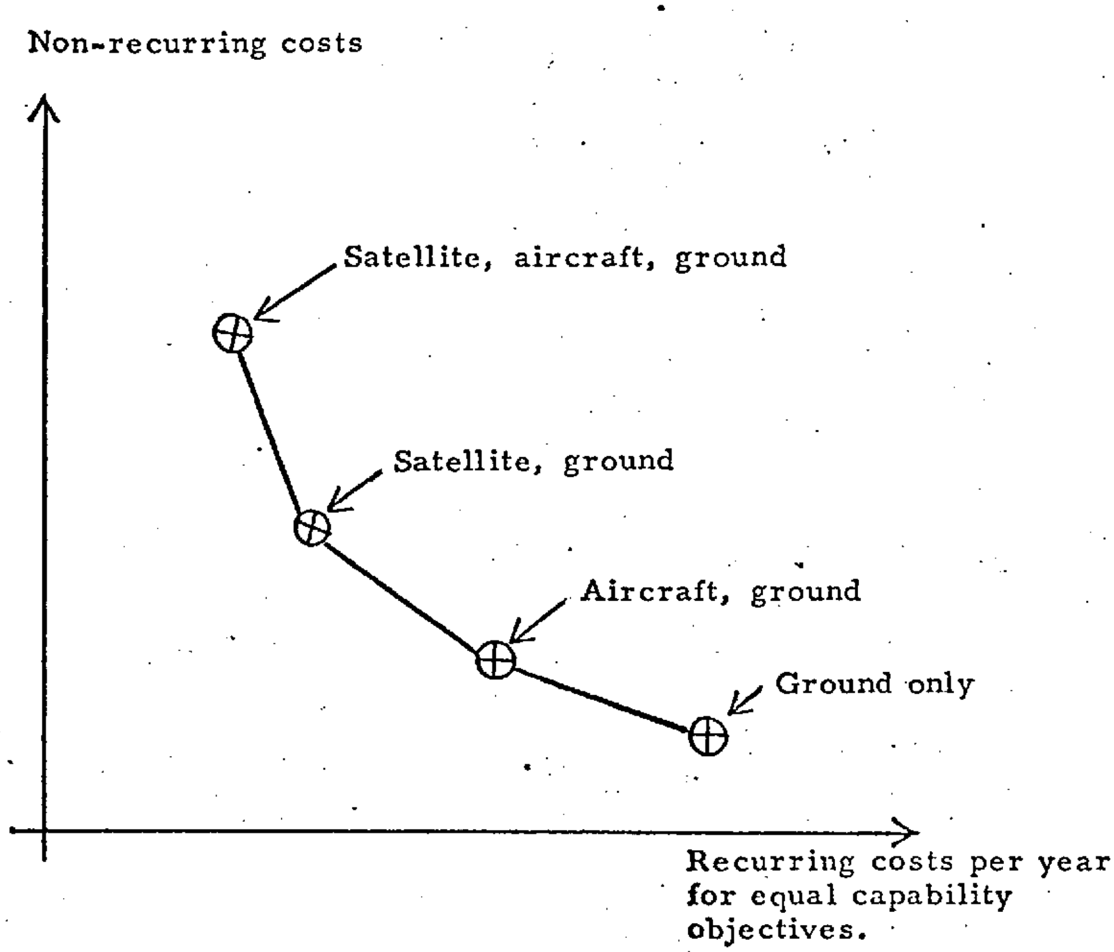
After repeating the analysis outlined above for each system the systems should be ranked and some indication should be given of recurring to non-recurring costs for each system.

2.9.1 Ranking

The systems should be ranked by their efficiency considerations as a minimum. Where non-efficiency considerations are important the systems should be ranked but the quantifiable benefits and costs should be kept separate from the efficiency consideration figures.

2.9.2 Trade-Off Analysis

For each system the results of the cost analysis should include a trade-off analysis which indicates the ratio of one-time costs to operational costs. For example



2.10 Cross Reference Chart

The following chart cross references the "steps in a cost-benefit analysis" and some of the "economic principles and quantitative methods" applied in these steps. The checks indicate where the particular principles and techniques are generally employed. Where possible, references are given both to the general cost-benefit literature and to the cost-benefit work Mathematica has done for NASA.

Steps in Cost-Benefit Analysis

Some Economic Principles and Quantitative Techniques	Statement of Objective & Assumption	Specification of System Alternatives	Classification: User	Classification: Geographic Area	Classification: Political Division	Classification: Beneficiaries	Efficiency Criteria – Economic Analysis – Benefit: Government Activity	Efficiency Criteria – Economic Analysis – Benefit: Private Activity	Efficiency Criteria – Economic Analysis – Cost: Government Activity	Efficiency Criteria – Economic Analysis – Cost: Private Activity	Non-Efficiency Criteria: Income Distribution Effects	Non-Efficiency Criteria: International Effects	Non-Efficiency Criteria: Environmental Effects	Non-Efficiency Criteria: Social Effects	System Selection	References
Time and Cost-Benefit Estimates																
Discounting							✓	✓	✓	✓						6, 8, 58, 37
Deflating							✓	✓	✓	✓						57
Planning Horizon	✓	✓					✓	✓	✓	✓						26
Infinite Horizon							✓	✓	✓	✓						4, 26
Dynamic Costing							✓	✓	✓	✓						19, 55
Uncertainty and Cost-Benefit Estimates																
Probability		✓					✓	✓	✓	✓						25, 56, 47
Risk Analysis		✓					✓	✓	✓	✓						25, 56
Learning Curves		✓							✓	✓						26
Sensitivity Analysis		✓					✓	✓	✓	✓					✓	25
Evaluation of Costs and Benefits																
Terms																
Opportunity Cost									✓	✓						4
Shadow Prices							✓	✓	✓	✓	✓					14, 36
Externalities			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		2, 14, 50
Derived Demand			✓			✓	✓	✓								61
Induced Demand			✓			✓	✓	✓								14, 26
Consumer Surplus			✓			✓	✓	✓			✓					6
Marginal Social Rate of Time Preference							✓	✓	✓	✓	✓			✓		8, 14, 37
Marginal Social Rate of Return on Investment							✓	✓	✓	✓				✓		8, 14, 37
Secondary Benefits (Costs)							✓	✓	✓	✓	✓	✓	✓	✓		10, 15
Techniques																
Optimization							✓	✓	✓	✓	✓				✓	2
Equal Cost/Unequal Benefit Analysis							✓	✓								26, 60
Unequal Cost/Equal Benefit Analysis									✓	✓						26, 60
Unequal Cost/Unequal Benefit Analysis							✓	✓	✓	✓						26, 60
Life Cycle Costing									✓	✓						26, 60
Parametric Cost Analysis									✓	✓						3
Function Specification and Fitting		✓					✓	✓	✓	✓						
Trade-off Analysis							✓	✓	✓	✓						6, 17, 23, 10
Incremental (Marginal) Analysis							✓	✓	✓	✓						23, 30
Abstract Commodity Approach							✓	✓								2
Supply and Demand Analysis							✓	✓	✓	✓						23, 60
Baumol-Oates Technique							✓		✓							49
Modeling		✓					✓	✓	✓	✓						59, 47

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PRINCIPLES OF

COST-BENEFIT ANALYSIS
FOR ERTS EXPERIMENTS

VOLUME II

Appendices

Prepared for

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VOLUME II

Appendix I. HYPOTHETICAL EXAMPLE

This appendix offers a hypothetical cost-benefit example employing a selected number of techniques and following the procedure outlined in Volume I.

Background of Hypothetical Example

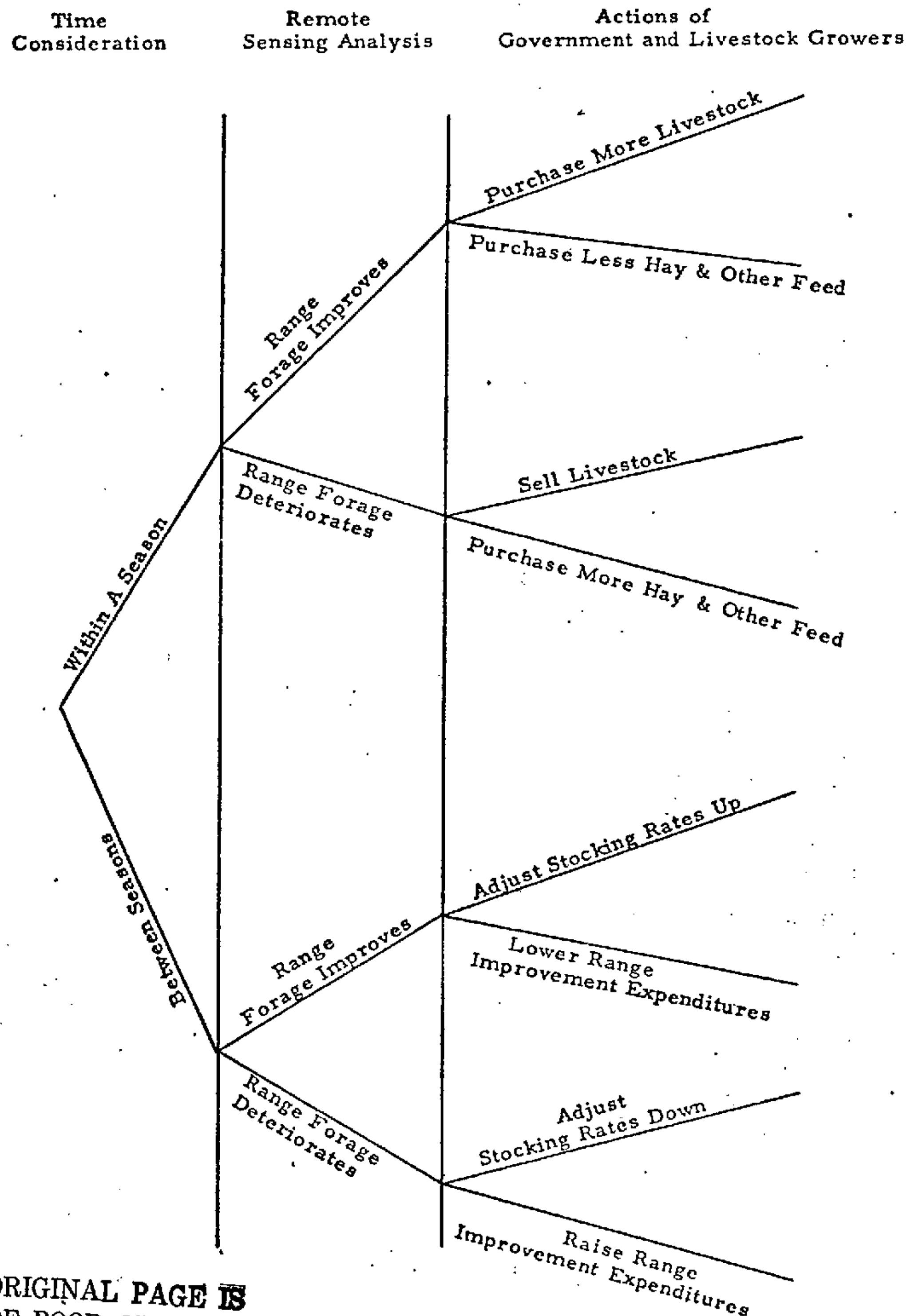
The Department of Interior does aerial surveys of public grazing lands. These surveys are used to allocate the grazing lands to livestock breeders and, on a more limited scale, to develop management plans.

The aerial surveys provide information on the immediate forage conditions and the long-range trend in forage conditions. This information can be used to determine where range conditions can be improved, e.g., by seeding, and whether livestock breeders should build up their herds or sell off some of their stock. These management plans in the long run should lower the cost of raising livestock and, therefore, the price of meat to the consumer. This management procedure is illustrated with a tree diagram in Figure IA-1.

Besides lower meat prices another benefit from remote sensing is less damage to grazing lands from over-grazing. Remote sensing provides a better guide to the number of animals a land area can bear than random assignment or assignment with superficial ground inspection.

Figure IA-1

The Use of Remote Sensing for Grazing Land Management



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The Objective

The objective is assumed to be an increase in remote sensing surveys of grazing lands, both public and private, in order to develop management plans to better utilize available forage and ultimately to lower the price of meat to consumers.

Assumptions

The surveys will be conducted for both public and private grazing lands (government lands are 27% of total grazing lands). Surveys will be taken 4 times within each year.

There are two types of classification errors. Type I is classifying land as available for larger stocking than it can bear. Type II is classifying land as unavailable for foraging when in fact it is available. The first error leads to land damage due to over grazing, the second error leads to higher feed costs when more expensive feeds are substituted in place of foraging.

It is assumed that the life of the project (planning horizon) will be ten years. The rate of discount will be ten percent.

An equal capability approach will be taken, i.e., each alternative remote sensing system will be assumed to survey the same land area. Therefore, the direct benefits from each alternative system will be the same but the cost reductions and direct costs will differ. Cost reductions will be considered as benefits and added to direct benefits to get total benefits.

It is further assumed that there are two aircraft equipped for aerial photography and a satellite which may be employed. They represent sunk costs, however, and the initial investment in them and the launch costs are not to be included in the calculations below.

Alternatives

The objective may be achieved by three alternative means:

1. Extended application of the aircraft surveys which are already undertaken.

2. Use of earth resources technology satellite.

3. A combined use of aircraft and satellite.

Classification - Aircraft Only System

It is assumed the remote sensing will be carried out by the government, specifically the Bureau of Land Management within the Department of the Interior will coordinate all efforts. The information will be dispensed to livestock breeders trade associations and individual breeders, the ultimate consumer of meat is the American consumer (international trade considerations are ignored in this example).

Benefits -- Aircraft Only System

A list of expected benefits may be found in Table IA-1. In this example, only the direct, induced, and cost savings benefits will be considered.

Figure IA-2 is a flowchart of the benefits model used for all three system alternatives. The benefits from meeting direct demand are the same for all three systems. The systems will differ in cost savings because the probability of a Type I or Type II error will differ. Aircraft surveys provide better resolution in photos than satellite surveys.

The benefits are a function of the land area surveyed (the activity level). It is assumed that the full benefits will not be realized and this is incorporated explicitly in the benefits model.

The model is (assuming a linear demand function)

$$B_1 = \Delta p \times Q_0$$

$$B_2 = \Delta p \times E \times Q_0 \times (\Delta p / P_0) \times .5$$

$$B_3 = L\,[(C_1\,T_1 + C_2\,T_2) - (C_1\,T_3 + C_2\,T_4]$$

$$B_T = (R)\,(A)\,[B_1 + B_2 + B_3]$$

where B_T = Total Benefits

B_1 = Potential Direct Benefits

B_2 = Potential Induced Benefits

B_3 = Cost Savings

R = Ratio of actual to potential benefits expected

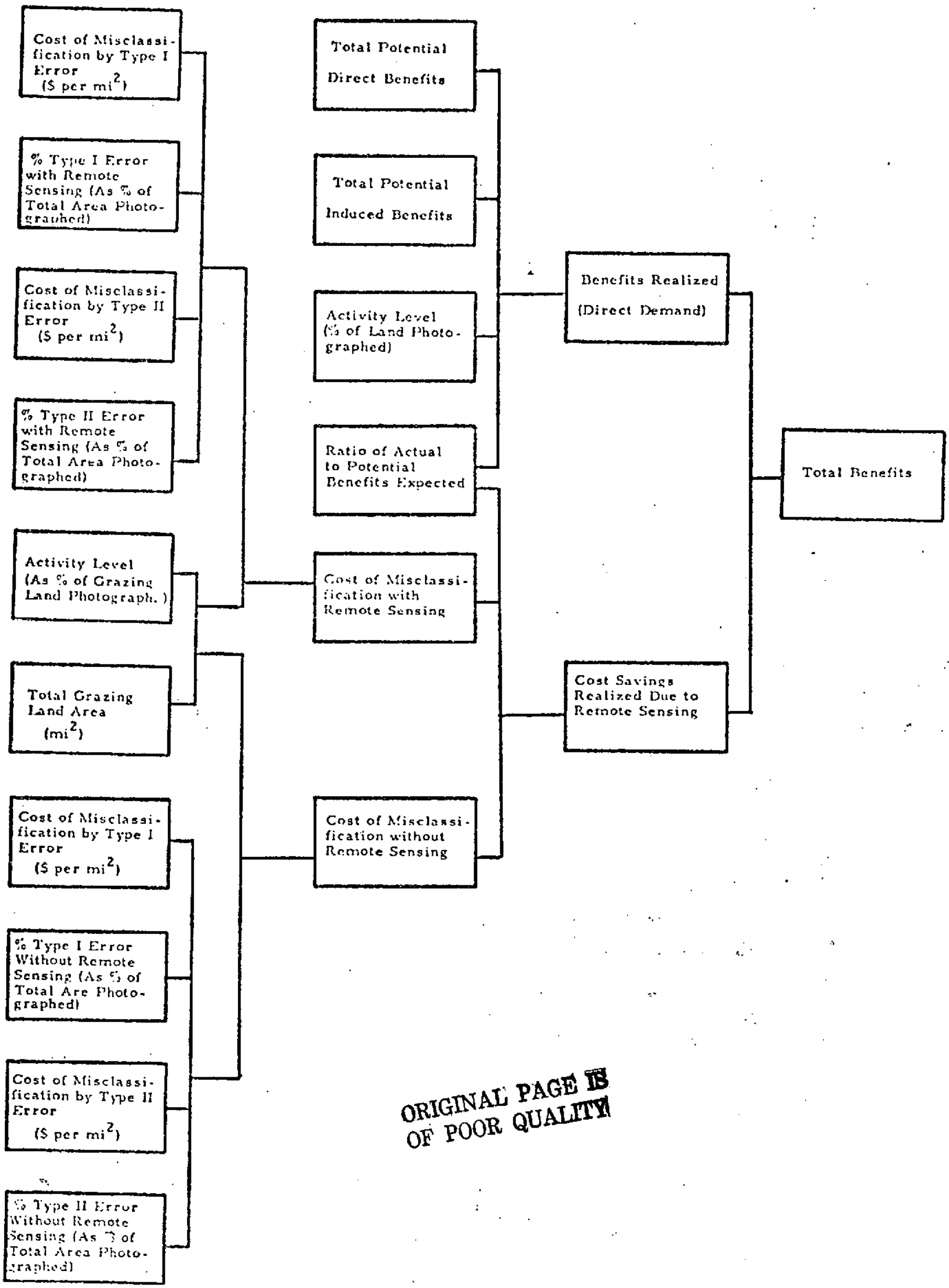
A = Activity level (% of land photographed)

L = Total grazing land area in U.S.

Table IA-1. Enumeration of Benefits

Form of Benefit	Domestic	International	Government	Private	Quantifiable	Non-Quantifiable	Probability that Benefit Will be Realized			Extent to Which Benefit Was Realized			Efficiency Consideration	Non-Efficiency Consideration (Secondary Effect)
							Possible	Likely	Certain	Partially	Almost Fully	Fully		
More Beef to Consumer	✓			✓	✓			✓					✓	
Lower Cost to Consumer	✓			✓	✓			✓					✓	
More Info to Farmer	✓			✓	✓			✓						✓
More Info to BLM	✓		✓		✓			✓						✓
Improve Trade Competitive Position		✓		✓		✓		✓						✓
Reduce Damage to Grazing Land	✓		✓	✓	✓			✓					✓	
Lower Production Costs to Farmers	✓			✓				✓						✓

Figure IA-2. Benefits Model



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Δp = Decrease in meat prices

P_0 = Original price

Q_0 = Original quantity

E = Elasticity of demand

C_1 = Cost of Type I error

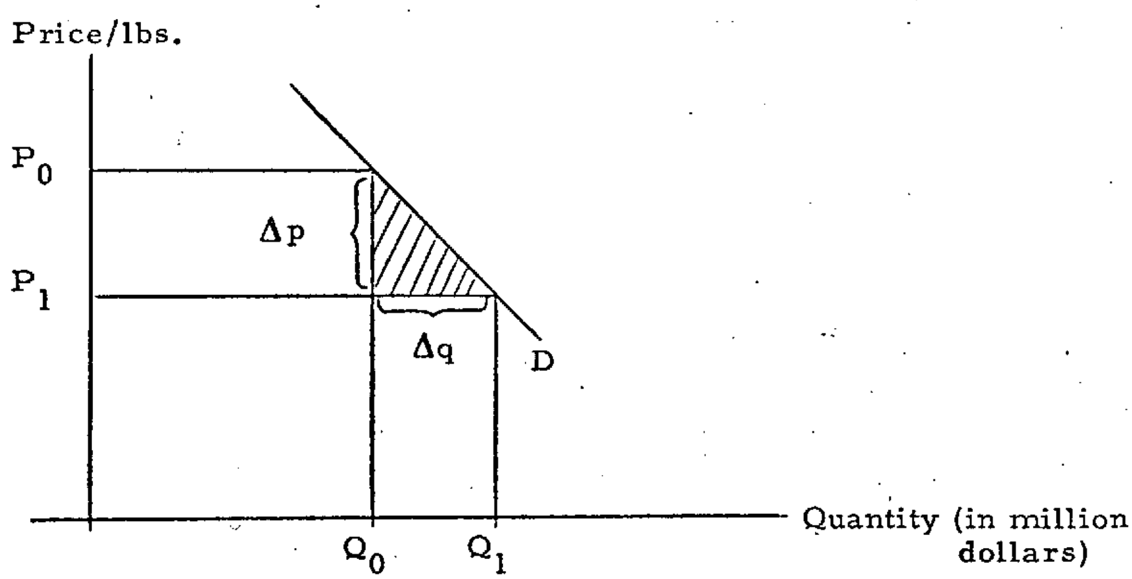
C_2 = Cost of Type II error

T_1 = Probability of Type I error using remote sensing system (i)

T_2 = Probability of Type II error using remote sensing system (i)

T_3 = Probability of Type I error without remote sensing

T_4 = Probability of Type II error without remote sensing.



Direct benefits = $\Delta p \times Q_0$

Induced benefits (shaded area) = $\Delta p \times \Delta q \times .5$

(Assuming a linear demand function)

Economists relate relative changes in price and quantity demanded by the concept of elasticity. Elasticity is defined as the percentage change in quantity due to a given percentage change in price. Or:

$$\text{Elasticity} = E = \frac{\frac{\Delta q}{Q_0}}{\frac{\Delta p}{P_0}}$$

We derive the induced benefit function with elasticity explicitly included as follows:

Induced Benefits Function

$$\begin{aligned} B_2 &= \Delta p \times \Delta q \times .5 \times \left(\frac{E}{E}\right) \\ &= \Delta p \times \Delta q \times .5 \times E \times (\Delta p/P_0)/(\Delta q/Q_0) \\ &= \Delta p \times \Delta q \times .5 \times E \times (\Delta p/P_0) \times (Q_0/\Delta q) \\ &= \Delta p \times .5 \times E \times (\Delta p/P_0) \times Q_0 \\ &= \Delta p \times E \times Q_0 \times (\Delta p/P_0) \times .5 \end{aligned}$$

Costs - Aircraft Only System

Figure IA-3 is a flowchart of the aircraft only cost model. The satellite only and the aircraft/satellite cost models are also included here as Figures IA-4 and IA-5.

Figure IA-3.

Aircraft Only Cost Model

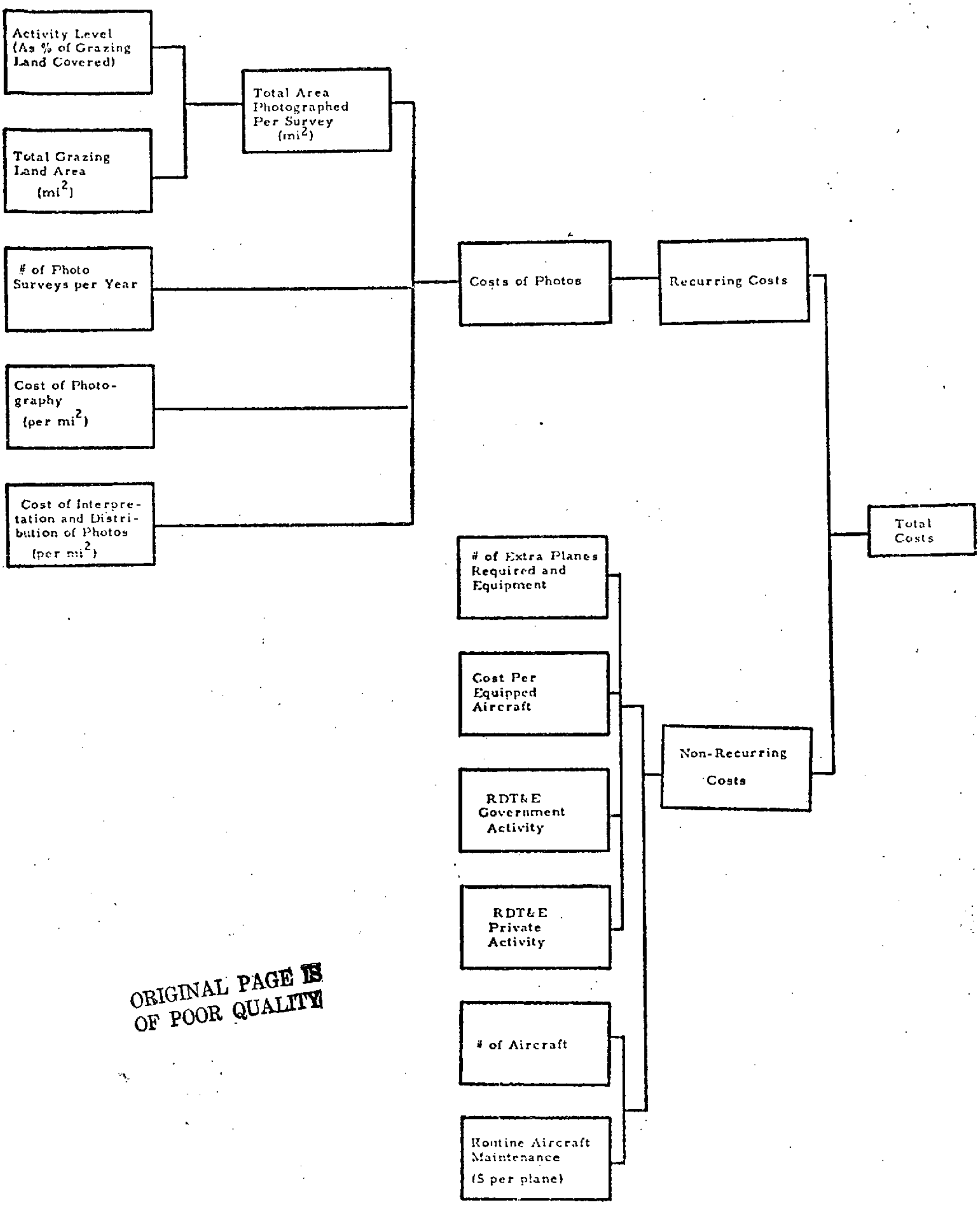


Figure IA-4

Satellite Only Cost Model

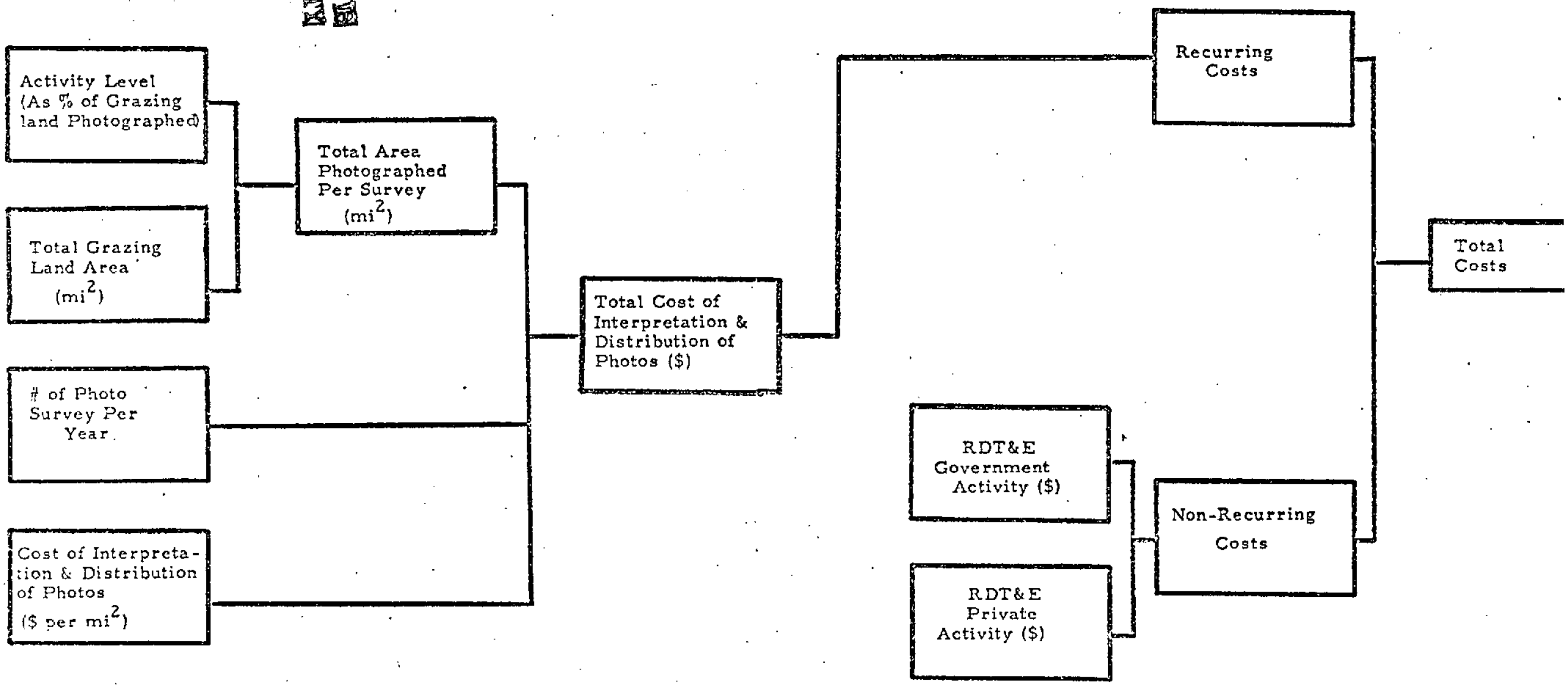
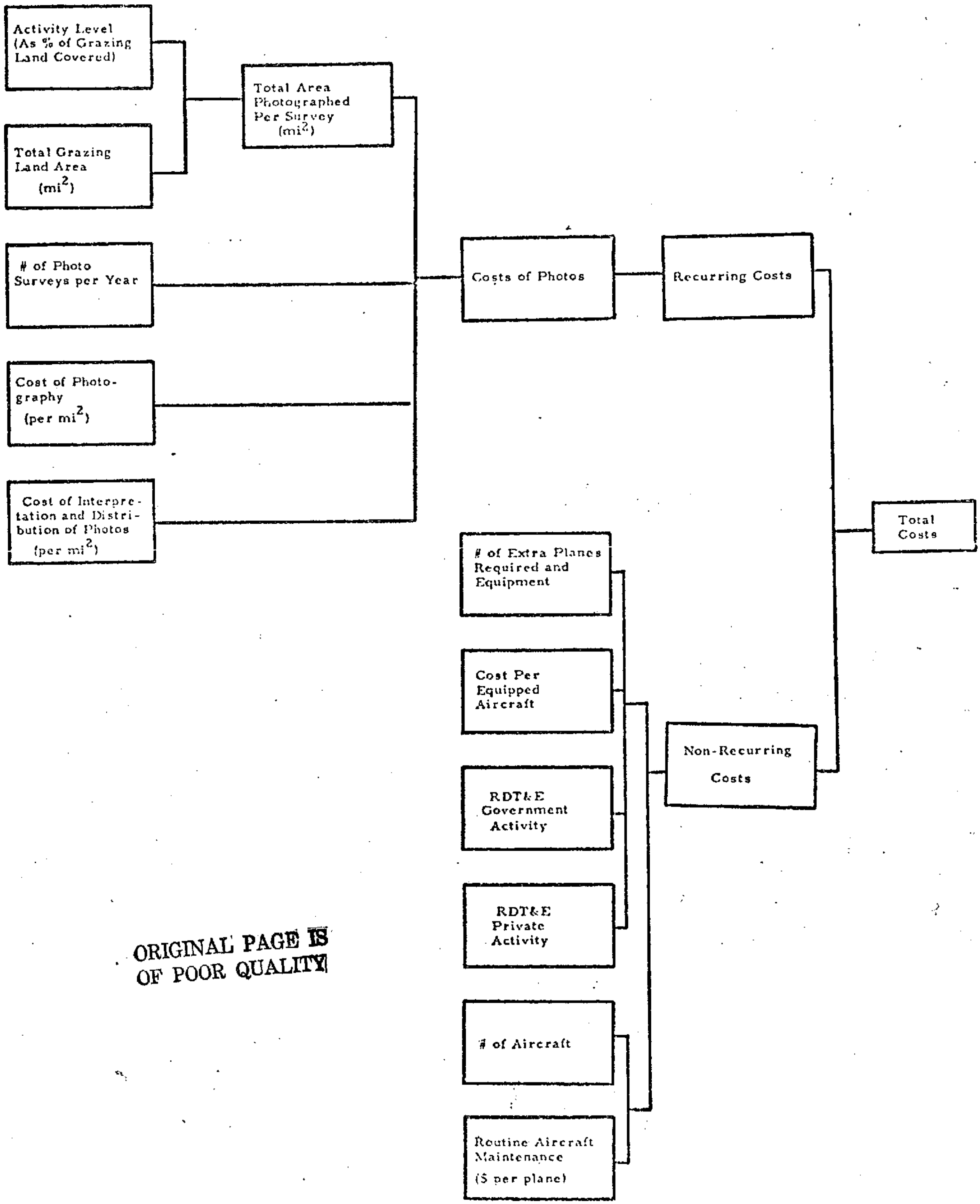


Figure IA-5

Aircraft/Satellite Cost Model



The aircraft only cost model is:

$$R = (L)\,(A)\,(S)\,[P_1 + P_2]$$

$$N = (X)\,(T) + R_g + R_p + (R_a)\,(M)$$

$$C = R + N$$

- C - Total costs
- R - Recurring costs
- N - Non-recurring costs
- L - Total grazing land area
- A - Activity level (As % of grazing land photographed)
- S - Number of surveys per year
- P_1 - Cost of photographing
- P_2 - Cost of interpretation and distribution
- X - Number of extra aircraft required
- T - Cost per equipped aircraft
- R_g - RDT&E for government activity
- R_p - RDT&E for private activity
- R_a - Number of aircraft required
- M - Routine maintenance costs per aircraft per year.

<u>Input Data</u>

The following figures were assumed for the most likely values:

- \$12,000 - Cost per mile squared of a Type I error (C_1)
- \$ 6,000 - Cost per mile squared of a Type II error (C_2)
- 2.5% - Probability of Type I error with aircraft (T_1)
- 3.0% - Probability of Type II error with aircraft (T_2)

3.0% - Probability of Type I error without remote sensing (T_3)

3.5% - Probability of Type II error without remote sensing (T_4)

1.36 million mi^2 - U.S. grazing land area (L)

\$1.26 - Initial price/lb. of meat (P_0)

\$0.0095 - Price change (Δp)

.42 - Elasticity of demand for meat (E)

11,000 million lbs - Initial quantity of meat demanded (Q_0)

4 - No. of surveys per year (S)

\$4.40 - Cost per mile squared of photographing (P_1)

\$2.20 - Cost per mile squared of interpreting and distributing photos (P_2)

10% - Discount rate

10 - Total aircraft required (R_a)

8 - No. of extra aircraft to be purchased (2 already available) (X)

\$1.83 mil - Cost of fully equipped aircraft (T)

\$530,000 - Cost of operation and maintenance per aircraft per year (M)

\$1.45 mil, \$.45 mil - RDT&E government expenditures in first two years of project (R_g)

\$.97 mil, \$.23 mil - RDT&E, private expenditures in first two years of project. (R_p)

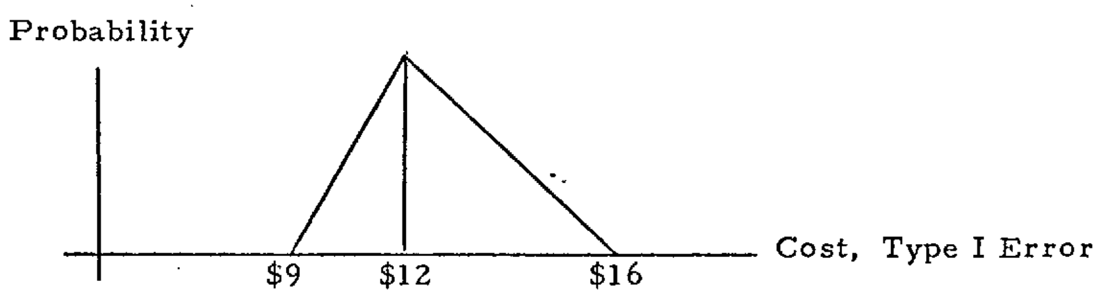
Activity levels and ratio of actual to potential benefits realized each year are indicated in the computer output below.

Note: It is assumed that the demand for meat grows at 2% a year due to population growth and income increments.

In addition to these most likely figures for each variable a probability distribution was assumed, e.g.

$$\left.\begin{array}{r}\$16{,}000 \text{ High} \\ 9{,}000 \text{ Low}\end{array}\right\} \text{Cost, Type I error}$$

triangular distribution



Monte Carlo simulations were run (1,000 runs) and the results of one iteration are present as computer output Tables 1 to 6.

The costs were distributed between the public and private sector by assuming that the cost of photographing would be passed on to the livestock breeders (private) but that the costs of interpretation and distribution, aircraft investment and maintenance would be borne by the government.

The summary of costs and benefits for this single iteration are presented in Table 5 of the computer output.

Ranking Systems

The above procedure was repeated for the satellite system and the aircraft/satellite system. The results are presented in Figure IA-6. On the basis of net present value the aircraft/satellite system is preferable.

TABLE 1

COSTS - GOVERNMENT ACTIVITY

(UNDISCOUNTED COSTS - IN MILLION DOLLARS)

SYSTEM ALTERNATIVE -- AIRCRAFT ONLY

FISCAL YEAR	NON-RECURRING COSTS		RECURRING COSTS		
	RDT&E	INVESTMENT	ACTIVITY LEVEL DEPENDENT	ACTIVITY LEVEL INDEPENDENT	ANNUAL COSTS
1974	0.97	14.64	3.01	5.30	23.93
1975	0.23	0.00	6.03	5.30	11.57
1976	0.00	0.00	6.03	5.30	11.34
1977	0.00	0.00	6.03	5.30	11.34
1978	0.00	0.00	6.03	5.30	11.34
1979	0.00	0.00	6.03	5.30	11.34
1980	0.00	0.00	6.03	5.30	11.34
1981	0.00	0.00	6.03	5.30	11.34
1982	0.00	0.00	6.03	5.30	11.34
1983	0.00	0.00	6.03	5.30	11.34
TOTALS	1.21	14.65	57.37	53.01	126.25

ITERATION NUMBER -- 714

TABLE 2

COSTS - PRIVATE ACTIVITY

(UNDISCOUNTED COSTS - IN MILLION DOLLARS)

SYSTEM ALTERNATIVE -- AIRCRAFT ONLY
****

	NON-RECURRING COSTS		RECURRING COSTS		
			ACTIVITY LEVEL	ACTIVITY LEVEL	ANNUAL
FISCAL YEAR	RDT&E	INVESTMENT	DEPENDENT	INDEPENDENT	COSTS
1974	1.45	0.00	5.94	0.00	7.39
1975	0.45	0.00	11.88	0.00	12.33
1976	0.00	0.00	11.88	0.00	11.88
1977	0.00	0.00	11.88	0.00	11.88
1978	0.00	0.00	11.88	0.00	11.88
1979	0.00	0.00	11.88	0.00	11.88
1980	0.00	0.00	11.88	0.00	11.88
1981	0.00	0.00	11.88	0.00	11.88
1982	0.00	0.00	11.88	0.00	11.88
1983	0.00	0.00	11.88	0.00	11.88
TOTALS	1.91	0.00	112.93	0.00	114.85

ITERATION NUMBER -- 714
***

TABLE 3

TOTAL COSTS

(UNDISCOUNTED COSTS - IN MILLION DOLLARS)

SYSTEM ALTERNATIVE -- AIRCRAFT ONLY
****

FISCAL YEAR	GOVERNMENT ACTIVITY	PRIVATE ACTIVITY	ANNUAL COSTS UNDISCOUNTED	DISCOUNT FACTOR	ANNUAL COSTS DISCOUNTED
1974	23.93	7.39	31.33	1.00	31.33
1975	11.57	12.33	23.91	0.90	21.73
1976	11.34	11.88	23.23	0.82	19.19
1977	11.34	11.88	23.23	0.75	17.45
1978	11.34	11.88	23.23	0.68	15.86
1979	11.34	11.88	23.23	0.62	14.41
1980	11.34	11.88	23.23	0.56	13.10
1981	11.34	11.88	23.23	0.51	11.91
1982	11.34	11.88	23.23	0.46	10.82
1983	11.34	11.88	23.23	0.42	9.84
TOTALS	126.25	114.85	241.11		165.70

ITERATION NUMBER -- 714
***

TABLE 4

BENEFITS

(IN MILLION DOLLARS)

SYSTEM ALTERNATIVE -- AIRCRAFT ONLY

FISCAL YEAR	POTENTIAL DIRECT BENEFITS	POTENTIAL INDUCED BENEFITS	COST SAVINGS	RATIO OF ACTUAL TO POTENTIAL BENEFITS	ACTIVITY LEVEL	ANNUAL BENEFITS REALIZED UNDISCOUNTED	ANNUAL BENEFITS REALIZED DISCOUNTED
1974	103.97	0.16	134.98	0.10	0.25	5.97	5.97
1975	106.25	0.16	134.98	0.17	0.50	20.52	18.65
1976	108.59	0.17	134.98	0.25	0.50	30.47	25.17
1977	110.98	0.17	134.98	0.25	0.50	30.76	23.11
1978	113.42	0.17	134.98	0.25	0.50	31.07	21.21
1979	115.92	0.18	134.98	0.25	0.50	31.38	19.47
1980	118.47	0.18	134.98	0.25	0.50	31.70	17.88
1981	121.08	0.19	134.98	0.25	0.50	32.03	16.42
1982	123.74	0.19	134.98	0.25	0.50	32.36	15.08
1983	126.46	0.19	134.98	0.25	0.50	32.70	13.85
TOTALS	1148.94	1.82	1349.90			279.02	176.88

ITERATION NUMBER -- 714

TABLE 5

COST-BENEFIT SUMMARY

(IN MILLION DOLLARS)

SYSTEM ALTERNATIVE -- AIRCRAFT ONLY
****

FISCAL YEAR	ANNUAL BENEFITS REALIZED DISCOUNTED	ANNUAL COSTS DISCOUNTED	ANNUAL NET PRESENT VALUE	CUMULATIVE PRESENT VALUE
1974	5.97	31.33	-25.35	-25.35
1975	18.65	21.73	-3.08	-28.43
1976	25.17	19.19	5.97	-22.45
1977	23.11	17.45	5.66	-16.79
1978	21.21	15.86	5.35	-11.44
1979	19.47	14.41	5.06	-6.38
1980	17.88	13.10	4.78	-1.60
1981	16.42	11.91	4.51	2.91
1982	15.08	10.82	4.25	7.16
1983	13.85	9.84	4.01	11.18
TOTALS	176.88	165.70	11.19	

ITERATION NUMBER -- 714
***

TABLE 6

INTERMEDIATE OUTPUTS

(UNDISCOUNTED COSTS - IN MILLION DOLLARS)

SYSTEM ALTERNATIVE -- AIRCRAFT ONLY
****

FISCAL YEAR	COST OF MISCLASSIFICATION: LAND DAMAGE: PUBLIC LAND	PRIVATE LAND	HIGHER FEED COSTS	COST OF PHOTO-GRAPHING	LAND AREA PHOTO-GRAPHED*	COST OF INTER-PRETATION AND DIS-TRIBUTION OF PHOTOS
1974	27.61	74.66	59.46	5.94	0.34	3.01
1975	55.22	149.31	118.93	11.88	0.68	6.03
1976	55.22	149.31	118.93	11.88	0.68	6.03
1977	55.22	149.31	118.93	11.88	0.68	6.03
1978	55.22	149.31	118.93	11.88	0.68	6.03
1979	55.22	149.31	118.93	11.88	0.68	6.03
1980	55.22	149.31	118.93	11.88	0.68	6.03
1981	55.22	149.31	118.93	11.88	0.68	6.03
1982	55.22	149.31	118.93	11.88	0.68	6.03
1983	55.22	149.31	118.93	11.88	0.68	6.03
TOTALS	524.67	1418.53	1129.87	112.93		57.37

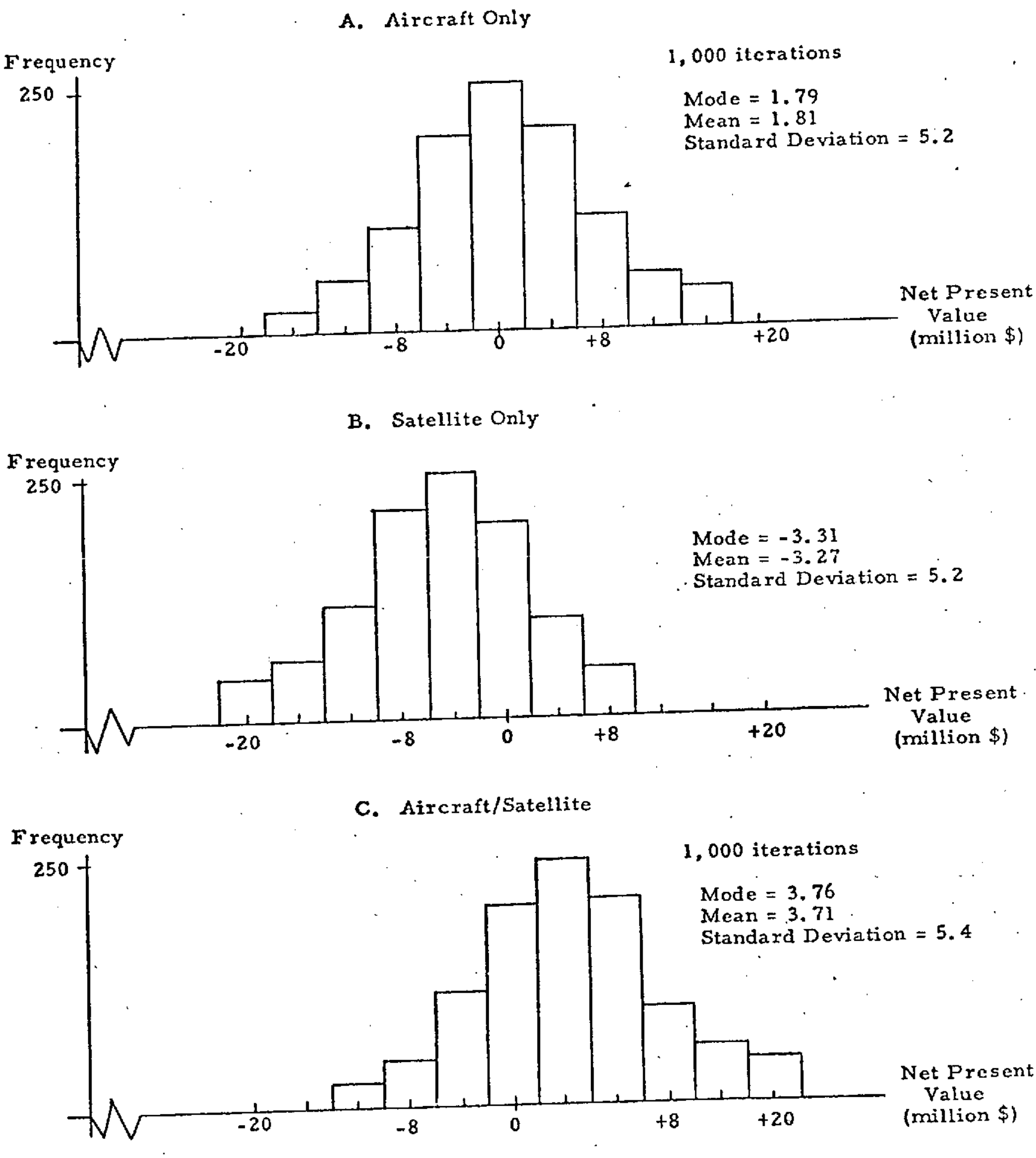
* - IN MILLION SQUARE MILES

TOTAL NUMBER OF PLANES -- 10

PERCENT OF GRAZING LAND PHOTOGRAPHED -- 50

ITERATION NUMBER -- 714
***

Figure IA-6. Results of Risk Analysis



Since the difference between the mean net present values of the aircraft system and the aircraft/satellite system is \$1.9 million (\$3.71-\$1.81) with a standard error of \$7.5 million ($\sqrt{(5.2)^2 + (5.4)^2}$) we may conclude:

There is a 60% probability that we will make the correct choice in selecting the aircraft/satellite system as more cost effective than the aircraft only system.

Also, since the difference between the mean net present values of the satellite only system and the aircraft/satellite system is \$6.98 million with a standard error of \$7.5 million we may conclude:

There is an 82% probability that we will make the correct choice in selecting the aircraft/satellite system as more cost effective than the satellite only system.

And finally we may conclude:

There is a 59% probability that we will make the correct choice in selecting the aircraft/satellite system as more cost effective than both the aircraft only system and the satellite only system.*

---

*Using Bayes' rule and defining A as the event that one system dominates the other two, B_1 the event aircraft/satellite (A/S) dominates aircraft only (A) or (A/S > A), B_2 the event (A > A/S), B_3 the event satellite (S) dominates A/S or (S > A/S) we get

$$P(B_1/A) = [P(B_1) \times P(A/B_1)]/[P(B_1) \times P(A/B_1) + P(B_2) \times P(A/B_2) + P(B_3) \times P(A/B_3)] = [.60 \times .82]/[(.60 \times .82) + (.40 \times .75) + (.18 \times .25)] = .588 = 59\%$$

Sensitivity Analysis

The sensitivity analysis in this section is performed for the aircraft only system which has served as an illustration above rather than the highest ranked system, the aircraft/satellite system.

The most likely values for the aircraft system were put into the computer model using a 10% discount rate and the results are found in the following computer output Tables 1 to 6. The program was run again changing only the discount rate to 5% first, then 15%. The results were

Discount Rate	Net Present Value	Benefits	Costs
5	$10.53 M	$207.85 M	$197.33 M
10	1.79	167.65	165.87
15	- 4.42	138.49	142.93

TABLE 1

COSTS - GOVERNMENT ACTIVITY

(UNDISCOUNTED COSTS - IN MILLION DOLLARS)

SYSTEM ALTERNATIVE -- AIRCRAFT ONLY
****

	NON-RECURRING COSTS		RECURRING COSTS		
FISCAL YEAR	RDT&E	INVESTMENT	ACTIVITY LEVEL DEPENDENT	ACTIVITY LEVEL INDEPENDENT	ANNUAL COSTS
1974	0.97	14.64	2.99	5.30	23.90
1975	0.23	0.00	5.98	5.30	11.51
1976	0.00	0.00	5.98	5.30	11.28
1977	0.00	0.00	5.98	5.30	11.28
1978	0.00	0.00	5.98	5.30	11.28
1979	0.00	0.00	5.98	5.30	11.28
1980	0.00	0.00	5.98	5.30	11.28
1981	0.00	0.00	5.98	5.30	11.28
1982	0.00	0.00	5.98	5.30	11.28
1983	0.00	0.00	5.98	5.30	11.28
TOTALS	1.21	14.65	56.85	53.01	125.73

MOSTLIKELY VALUES
****

TABLE 2

COSTS - PRIVATE ACTIVITY

(UNDISCOUNTED COSTS - IN MILLION DOLLARS)

SYSTEM ALTERNATIVE -- AIRCRAFT ONLY
****

	NON-RECURRING COSTS		RECURRING COSTS		
FISCAL YEAR	RDT&E	INVESTMENT	ACTIVITY LEVEL DEPENDENT	ACTIVITY LEVEL INDEPENDENT	ANNUAL COSTS
1974	1.45	0.00	5.98	0.00	7.43
1975	0.45	0.00	11.96	0.00	12.42
1976	0.00	0.00	11.96	0.00	11.97
1977	0.00	0.00	11.96	0.00	11.97
1978	0.00	0.00	11.96	0.00	11.97
1979	0.00	0.00	11.96	0.00	11.97
1980	0.00	0.00	11.96	0.00	11.97
1981	0.00	0.00	11.96	0.00	11.97
1982	0.00	0.00	11.96	0.00	11.97
1983	0.00	0.00	11.96	0.00	11.97
TOTALS	1.91	0.00	113.70	0.00	115.62

MOSTLIKELY VALUES
****

TABLE 3

TOTAL COSTS

(UNDISCOUNTED COSTS - IN MILLION DOLLARS)

SYSTEM ALTERNATIVE -- AIRCRAFT ONLY

FISCAL YEAR	GOVERNMENT ACTIVITY	PRIVATE ACTIVITY	ANNUAL COSTS UNDISCOUNTED	DISCOUNT FACTOR	ANNUAL COSTS DISCOUNTED
1974	23.90	7.43	31.34	1.00	31.34
1975	11.51	12.42	23.94	0.90	21.76
1976	11.28	11.97	23.26	0.82	19.21
1977	11.28	11.97	23.26	0.75	17.47
1978	11.28	11.97	23.26	0.68	15.88
1979	11.28	11.97	23.26	0.62	14.43
1980	11.28	11.97	23.26	0.56	13.12
1981	11.28	11.97	23.26	0.51	11.92
1982	11.28	11.97	23.26	0.46	10.84
1983	11.28	11.97	23.26	0.42	9.85
TOTALS	125.73	115.62	241.37	—	165.87

MOSTLIKELY VALUES

TABLE 4

BENEFITS

(IN MILLION DOLLARS)

SYSTEM ALTERNATIVE -- AIRCRAFT ONLY
****

FISCAL YEAR	POTENTIAL DIRECT BENEFITS	POTENTIAL INDUCED BENEFITS	COST SAVINGS	RATIO OF ACTUAL TO POTENTIAL BENEFITS	ACTIVITY LEVEL	ANNUAL BENEFITS REALIZED UNDISCOUNTED	ANNUAL BENEFITS REALIZED DISCOUNTED
1974	104.50	0.16	122.39	0.10	0.25	5.67	5.67
1975	106.58	0.16	122.39	0.17	0.50	19.47	17.70
1976	108.72	0.17	122.39	0.25	0.50	28.91	23.88
1977	110.89	0.17	122.39	0.25	0.50	29.18	21.92
1978	113.11	0.17	122.39	0.25	0.50	29.46	20.11
1979	115.37	0.18	122.39	0.25	0.50	29.74	18.46
1980	117.68	0.18	122.39	0.25	0.50	30.03	16.94
1981	120.03	0.19	122.39	0.25	0.50	30.32	15.55
1982	122.43	0.19	122.39	0.25	0.50	30.62	14.27
1983	124.88	0.19	122.39	0.25	0.50	30.93	13.10
TOTALS	1144.25	1.82	1224.00			264.39	167.65

MOSTLIKELY VALUES
****

TABLE 5

COST-BENEFIT SUMMARY

(IN MILLION DOLLARS)

SYSTEM ALTERNATIVE -- AIRCRAFT ONLY
****

FISCAL YEAR	ANNUAL BENEFITS REALIZED DISCOUNTED	ANNUAL COSTS DISCOUNTED	ANNUAL NET PRESENT VALUE	CUMULATIVE PRESENT VALUE
1974	5.67	31.34	-25.66	-25.66
1975	17.70	21.76	-4.05	-29.72
1976	23.88	19.21	4.66	-25.05
1977	21.92	17.47	4.44	-20.60
1978	20.11	15.88	4.23	-16.36
1979	18.46	14.43	4.02	-12.34
1980	16.94	13.12	3.82	-8.52
1981	15.55	11.92	3.62	-4.89
1982	14.27	10.84	3.43	-1.46
1983	13.10	9.85	3.25	1.78
TOTALS	167.65	165.87	1.79	

MOSTLIKELY VALUES
****

TABLE 6

INTERMEDIATE OUTPUTS

(UNDISCOUNTED COSTS - IN MILLION DOLLARS)

SYSTEM ALTERNATIVE -- AIRCRAFT ONLY
****

	COST OF MISCLASSIFICATION					
	LAND DAMAGE		HIGHER	COST OF	LAND AREA	COST OF INTER-PRETATION AND DIS-
FISCAL YEAR	PUBLIC LAND	PRIVATE LAND	FEED COSTS	PHOTO-GRAPHING	PHOTO-GRAPHED*	TRIBUTION OF PHOTOS
1974	27.54	74.46	61.20	5.98	0.34	2.99
1975	55.08	148.92	122.40	11.96	0.68	5.98
1976	55.08	148.92	122.40	11.96	0.68	5.98
1977	55.08	148.92	122.40	11.96	0.68	5.98
1978	55.08	148.92	122.40	11.96	0.68	5.98
1979	55.08	148.92	122.40	11.96	0.68	5.98
1980	55.08	148.92	122.40	11.96	0.68	5.98
1981	55.08	148.92	122.40	11.96	0.68	5.98
1982	55.08	148.92	122.40	11.96	0.68	5.98
1983	55.08	148.92	122.40	11.96	0.68	5.98
TOTALS	523.27	1414.77	1162.82	113.70		56.85

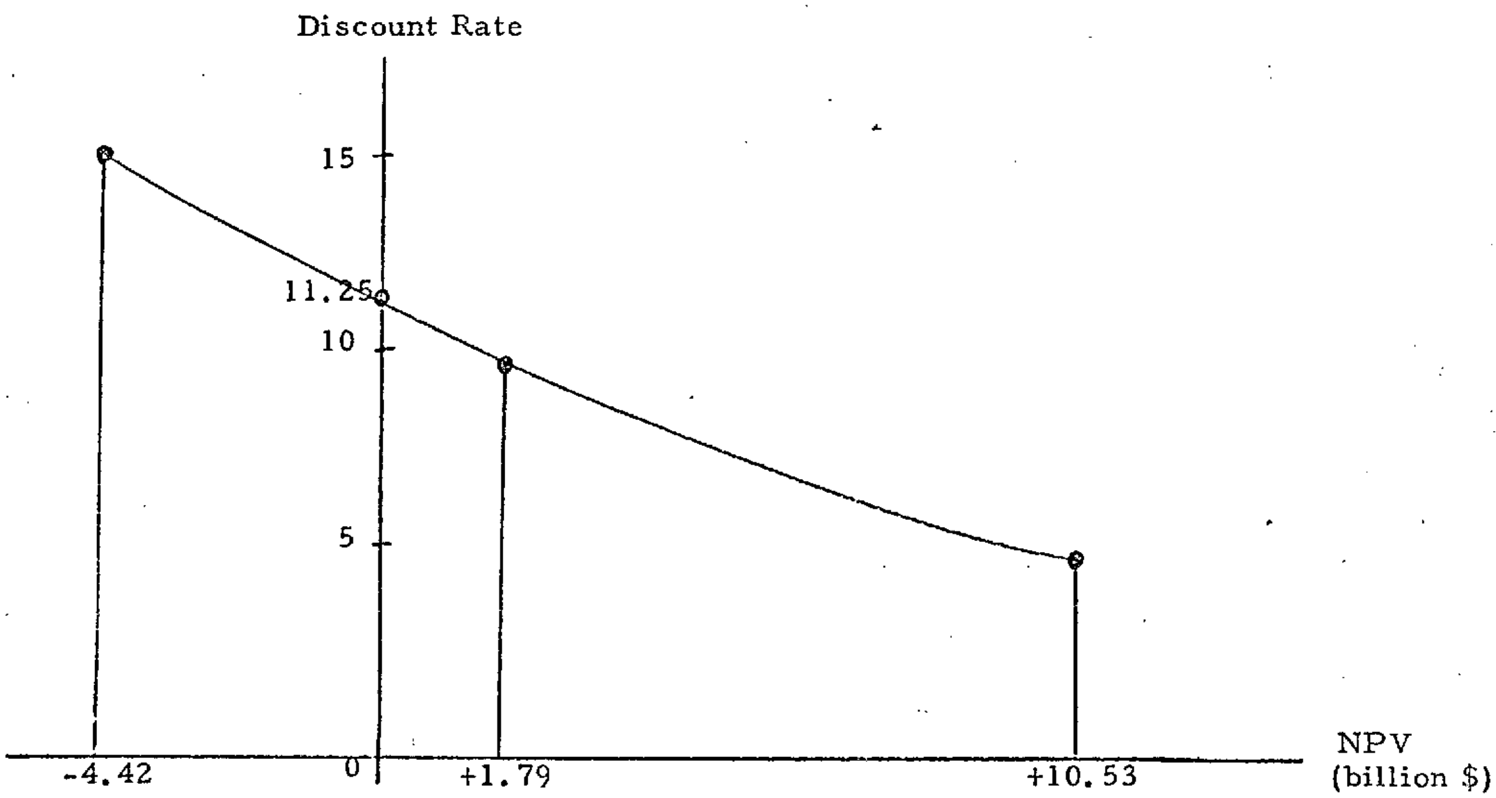
* - IN MILLION SQUARE MILES

TOTAL NUMBER OF PLANES -- 10

PERCENT OF GRAZING LAND PHOTOGRAPHED -- 50

These results may be illustrated as follows:

Aircraft Only System



The rate of return (where discount rate gives a net present value of zero) for the aircraft system is 11.25%.

The different results indicate that benefits in this project will be realized gradually in time and if less value (i.e., higher discount rate) is given to future benefits then the system will be considered less desirable.

Other variables were perturbed one at a time and the results are presented as Table IA-6.

Table IA-6 indicates that the most sensitive variables are the probabilities of misclassifying land by a type I or type II error and the percentage of potential benefits of which livestock growers can take advantage.

Tables IA-6

Sensitivity Analysis

(In Million Dollars)

Perturbed Variable*	Resulting Total Net Present Value	Variation from Unperturbed Case
Ratio-Actual to Potential Benefits	18.56	+16.77
Percentage Change in Meat Prices	9.90	+ 8.11
Quantity of Meat Demanded	9.89	+ 8.10
Cost Due to Error Type I	7.57	+ 5.78
Activity Level	7.33	+ 5.54
Cost Due to Error Type II	4.68	+ 2.89
Shift in Demand Over Time	2.51	+ 0.72
Elasticity of Demand	1.81	+ 0.02
Cost of Interpretation & Distribution	-1.94	- 3.73
Cost of Photographing	-5.69	- 7.48
Probability of Type II Error	-15.53	-17.32
Probability of Type I Error	-27.09	-28.88

*Perturbation = Ten Percent Increase

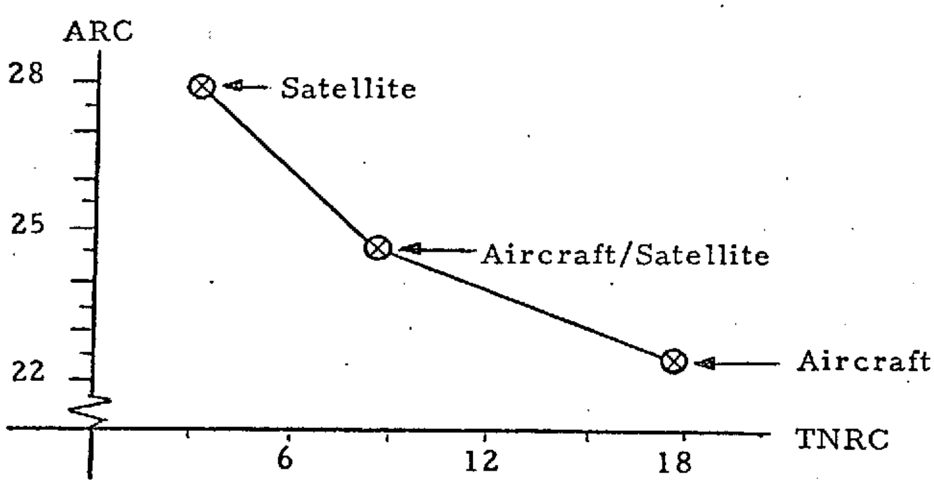
Trade-off Analysis

If we compare the total non-recurring costs (TNRC) to the annual recurring costs (ARC) for each of the alternative systems we derive a trade-off function between initial investment and operating expenses with equal capability.

System Costs

(in million dollars)

	Aircraft Only	Satellite Only	Aircraft/Satellite
TNRC	$17.75	$ 3.12	$ 8.71
ARC	22.33	27.84	24.66



Appendix II. ELABORATION OF SOME ECONOMIC PRINCIPLES

A. Planning Horizon

The assumed "economic uselife" of an investment project is normally something shorter than infinite because of one or a combination of the following factors:

1. Factors Inherent in the Project Itself:

   a. One of the physical inputs to the project depreciates over time, collapses at a point in time (one hoss-shay depreciation) or becomes unavailable at a point in time (e.g., a rented piece of land, or an exhaustible supply of raw materials).

   b. The demand for the product or service yielded by the project may drop off or disappear altogether after some time.

2. Factors Inherent in the Decisionmaker:

   a. The decisionmaker is risk averse and deliberately chooses a finite and possibly short investment horizon as a risk adjustment.

   b. The decisionmaker limits the investment horizon to his own life expectancy.

Since the present discussion is concerned exclusively with public investments in satellite systems, item 2(b) above can be dismissed from consideration altogether. Furthermore, it has been argued in an earlier report by Mathematica [8] and in the pertinent economic literature at large [63] that the government should not be risk averse in evaluating alternative public projects. This means that a public agency should not, because of risk averseness, shorten the investment horizon (N) of a public project arbitrarily. On the basis of this argument, item 2(a) above can be eliminated from consideration as well.

With respect to item 1(b) above, it can probably be assumed that with growing industrialization and population density there will continue to be a steady -- or even increasing -- demand for earth observation, at least for the next four to five decades. But at discount rates greater than, say, 5 percent, the present value of a steady stream of annual benefits increases only at a sharply diminishing rate with increases in the investment horizon, as is indicated in Figure A-15 for one specific case.

In Figure IIA-1 the symbol PV $(\bar{r}, N)$ denotes the present value of a steady stream of annual benefits obtained for N consecutive years and discounted at some discount rate $\bar{r} > 5$ percent. As may be inferred from Figure IIA-2 the assumption of a 40 or 50 year project horizon is nearly equivalent to assuming, for purposes of evaluation, an <u>infinite horizon</u>. Thus, if it is reasonable to assert that the demand for earth oriented remote sensing programs will continue into the indefinite future, one really needs to be certain only that it will continue for at least the next four to five decades.

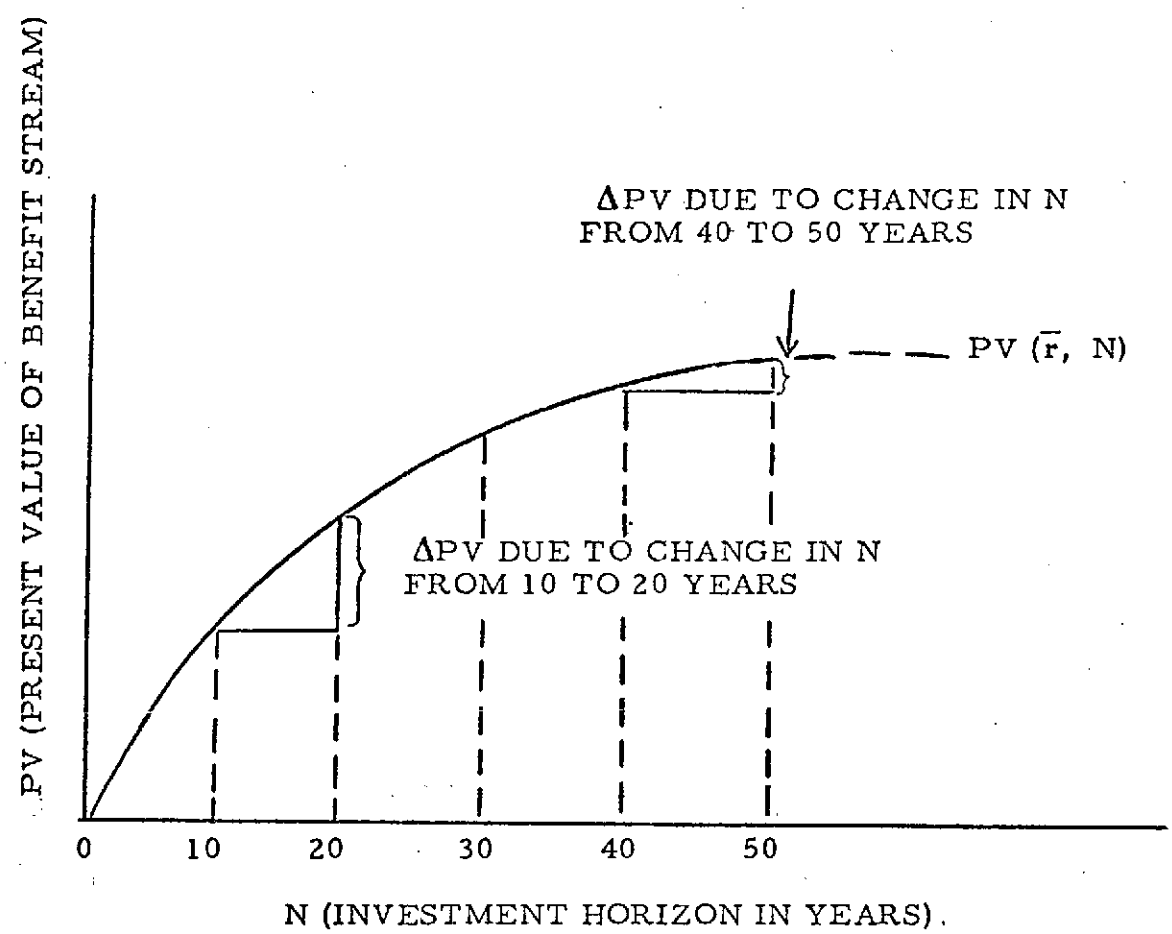


Figure IIA-1. The Effect of the Investment Horizon (N) on The Present Value of a Steady Stream of Benefits

The formula, with an infinite planning horizon, is:

$$PV = \left[\sum_{t=1}^{n} \frac{B_t}{(1+\gamma)^t}\right] + \left[\frac{B_n}{\gamma\,(1+\gamma)^n}\right]$$

The terms are as defined on page 4 of Volume I, except for n which is now defined as the year in which benefits stabilize at some steady stream value. The formula implies the benefits accrue in lump sum at the end of each year.

This leaves us with point a(a) above, i.e., with the question of whether a physical input into ERTS-1 type program will become unavailable at some future point in time, and if so, when.

Since the blueprints and documentation for ERTS-1 type systems exist and any number of identical or upgraded satellites can be built, point a(a) can also be eliminated from consideration.

The argument for an infinite horizon evaluation may be made from a second viewpoint which is made with reference to Figure IIA-2.

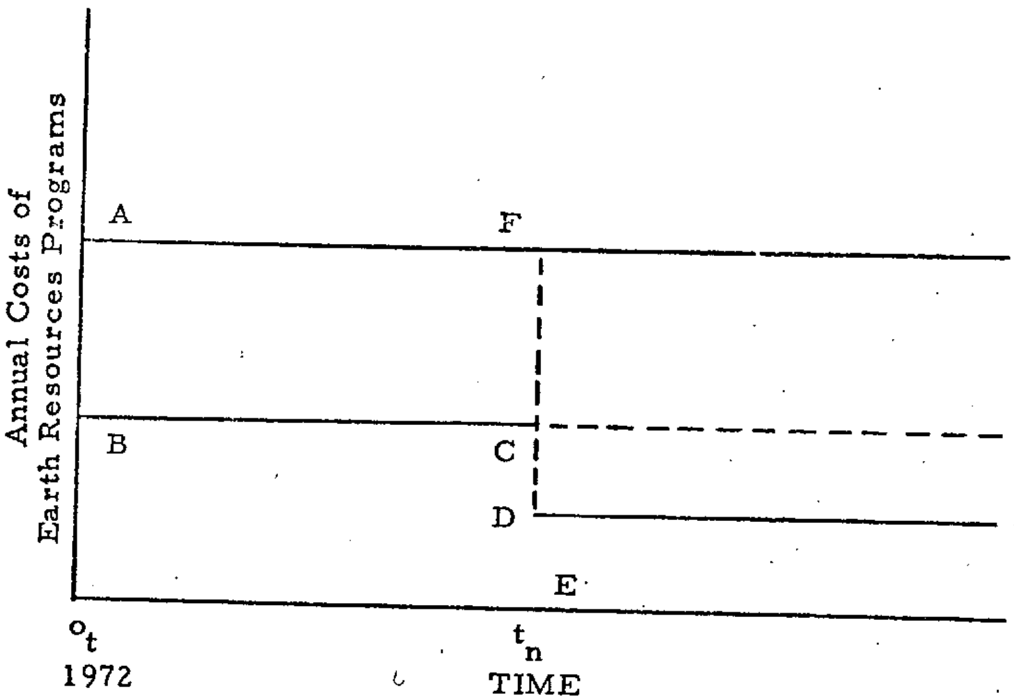


Figure IIA-2. Illustration of the Project Horizon

The assumption is made, as above, that an earth resources survey program will continue into the indefinite future. It is further assumed that the annual cost of the earth resources survey program by conventional means is OA and with the aid of ERTS-1 type technology it is OB. The economic benefits attributable to the ERTS-1 technology are BA per year. Based upon an equal capability analysis, it is expected that at some point in time, say, t_n, that a technological advance will occur that further reduces the cost of the program to ED per year, realizing an additional savings of DC per year. It would be an error to attribute to the new technology DF in annual savings even though it replaces the ERTS-1 technology that will be under study. Any decision to introduce the new technology should be based upon its incremental benefits, DC versus its incremental developmental costs. So long as there is an earth resources survey program, the original savings should be attributed to the ERTS-1 type technology, which is an infinite horizon approach for each feasible investment alternative presently definable.

B. Social Rate of Discount - The Theoretical Underpinnings

Briefly, society's rate of time preference may be defined as a rate of interest which reflects consumers' subjective, relative evaluation of given quantities of consumables one year hence; then their rate of time preference is said to be $0.05 = \left[\frac{105}{100}\right] - 1 = 5$ percent. Alternatively the rate of time preference may be defined as the rate of interest which consumers would have to be offered in order to persuade them to sacrifice additional current consumption in favor of additional future consumption.

Any investment project -- public or private -- involves the sacrifice of consumables at some point in time for the sake of increased consumption at one or more subsequent points in time.[1] From the very definition of the rate of time preference, it is clear that this rate must somehow be reflected in the social rate of discount used in the evaluation of public projects.

There is, however, still another side to the social discount rate: the social opportunity costs of a public project are the benefits foregone when the economic resources used by the project are diverted from the private to the public sector. The social rate of discount should reflect these opportunity costs as well.

Let us assume, for example, that all of the resources devoted to a public project would have been used in the private sector for investment outlays promising an annual rate of return of 10% before corporate income taxes and after an allowance for the eventual replacement of worn out equipment. Suppose $1 billion in resources were transferred to the public project. Then the public project could be justified economically only if it also promised a benefit stream (necessarily accruing to members of the private sector at large) equivalent to an annual benefit stream of $100 million (10% of $1 billion). An alternative way of expressing this is that the present value of the benefit stream produced by the public project, discounted at $r = 10\%$, must be at least as high as $1 billion, or that the net present value (NPV) of the project must be greater than or at least equal to zero.

---

[1] It may seem unusual to see the output from a remote sensing system defined as a consumable. The point is that the output from ERTS-1 becomes input into production processes which ultimately do yield consumable

The interest rate concept used in the preceding paragraph is sometimes referred to as the time productivity of economic resources. It is the rate of return which society is able to earn in the private sector by sacrificing current consumption in favor of future consumption, i.e., by investing economic resources in productive investment projects. In contrast, society's rate of time preference is the rate of return for which society is willing to sacrifice current consumption for the sake of increased future consumption. These two interest-rate concepts should not be confused: the rate of time productivity is an objective, technical concept; the rate of time preference, on the other hand, is a purely subjective magnitude.

It can be shown that, in the imaginary world of classical economics, the savings and investment behavior of society -- through the nation's capital markets -- would always drive the economy to an equilibrium position in which all individuals exhibit the same (social) rate of time preference, all investors face the same (social) rate of time productivity and in which, moreover, the social rate of time preference would be just equal to the social rate of time productivity. This overall equilibrium market rate of interest would then be the appropriate discount rate to be used for public-project evaluation. See [8]

Unfortunately, the real world differs significantly from the happy state of affairs in the classical model. For one, individual investors face different degrees of risk and differ in their attitudes toward risk. The rate of return required by private investors therefore include risk premiums which differ over the spectrum of investor.

Secondly, the tax system does not treat all investors in the private sector equally. Corporations, for example, face tax rates that differ from those paid by unincorporated businesses, and there are also differences in the rates paid by different unincorporated business firms. To earn the same after-tax rate of return, different business firms must therefore earn different pre-tax rates of returns on their marginal investments.

Finally, net-savers in our economy typically obtain rates of return on their savings that differ from the rates faced by net borrowers. Different consumers therefore are characterized by different rates of time preference.

In short, then, in the real world there exists no single market rate of interest which can be viewed as the appropriate discount rate for public project evaluation. The rate being used for that purpose must therefore be a weighted average of the various rates prevailing in the market.

In the real world, a resource transfer from the private to the public sector does not usually come solely from private investment projects part of the resources will surely come from private consumption. It follows that the opportunity costs of the resource transfer must reflect not only the spectrum of rates of return on foregone private investments, but also the spectrum of time preference rates of those who sacrificed current consumption. This requirement confronts one with enormous difficulties in any attempt to estimate the appropriate level of the social discount rate for practical applications of benefit-cost analyses.[1]

---

[1] This has been thoroughly dealt with in [8] .

Suffice it to say that the fundamental idea underlying this estimation process is always the same; one seeks to estimate the magnitude of the sacrifice borne by the private sector when resources are transferred from private consumption or investment to public-sector use, and to express this sacrifice in the form of an annual rate of return, r.

The Level of the Social Rates of Discount in the United States

Table IIA-1 presents a sample of discount rates estimated with painstaking effort by various professional economists. It should be emphasized that the economists' estimates were made at different points in time, i.e., under different capital-market conditions. But this circumstance alone cannot explain the wide variation in these estimates; rather, the variation reflects for the most part differences in the conceptual framework used by these economists.

From existing surveys it is apparent that historically neither the various U. S. government agencies nor professional economists have so far been able to agree on an appropriate social rate of discount. The rates of discount implicitly or explicitly adopted by Federal agencies span a range from 0 percent to 15 percent. (In some cases this rate actually may be less than zero when outright subsidies are given in the financing of projects with a negative return in undiscounted dollars). The rates suggested by economists span the somewhat smaller range from 4 percent to roughly 14 percent.

In view of the prevailing uncertainty about the proper social rate of discount, some economists would prefer not to select a unique discount

Table IIA-1

Social Rates of Discount Recommended by Various Economists

Author	Year	Rate
Krutilla and Eckstein	1958	5 to 6 percent
Hirschleifer, DeHaven, and Milliman	1960	10 percent
Hufschmidt, Krutilla and Margolis	1961	4 to 5 percent
Weisbrod	1960	10 percent
Friedlaender	1965	5 percent[1]
Bain, Caves and Margolis	1966	5 to 6 percent
Stockfish	1967	13.5 percent
Baumol	1968	10 percent
Eckstein	1968	8 percent
Harberger	1968	10.68 percent

[1] The author adjusts for risk by assuming a relatively short use life for the (highway) investment project being evaluated.

Source: J. Hirschleifer and D. L. Shapiro, Table 1, pp. 517, of author's publication.

rate at all, but instead to evaluate public projects in terms of an entire set of alternative rates. For want of a better term, we shall call this method the flexible approach. Pushed to its logical limit, the flexible approach amounts to the derivation of the net present value curves for all projects being evaluated for a reasonable range of discount rates, say from zero to 10 percent. The overall evaluation can then be presented simply in terms of a diagram such as Figure IIIA-3 which depicts the discount-rate sensitivity of three hypothetical investment projects.

The advantage of the flexible approach is immediately apparent from Figure IIA-3. For Alternative 1, the approach clearly indicates acceptance of the project for the example chosen, since the project has a positive net present value over both the range of discount rates suggested by economists (4 to 14 percent) and that suggested by federal agencies (0 to 15 percent). Similarly, Alternative 3 would probably be rejected since it has a positive net present value only at rates lower than those recommended by economists. The more flexible approach thus provides one with information about the sensitivity of the acceptance criterion to the analyst's assumptions concerning the discount rate.

However, the flexible approach is not particularly helpful in one's evaluation of Alternative 2. Clearly, it is small comfort to know that there are some rates, acceptable to some analysts, at which Alternative 2 would be acceptable, when there is also an entire range of recommended rates at which the project would be deemed to be "uneconomic". In other words, for Alternatives such as 2 the flexible approach begs the question entirely.

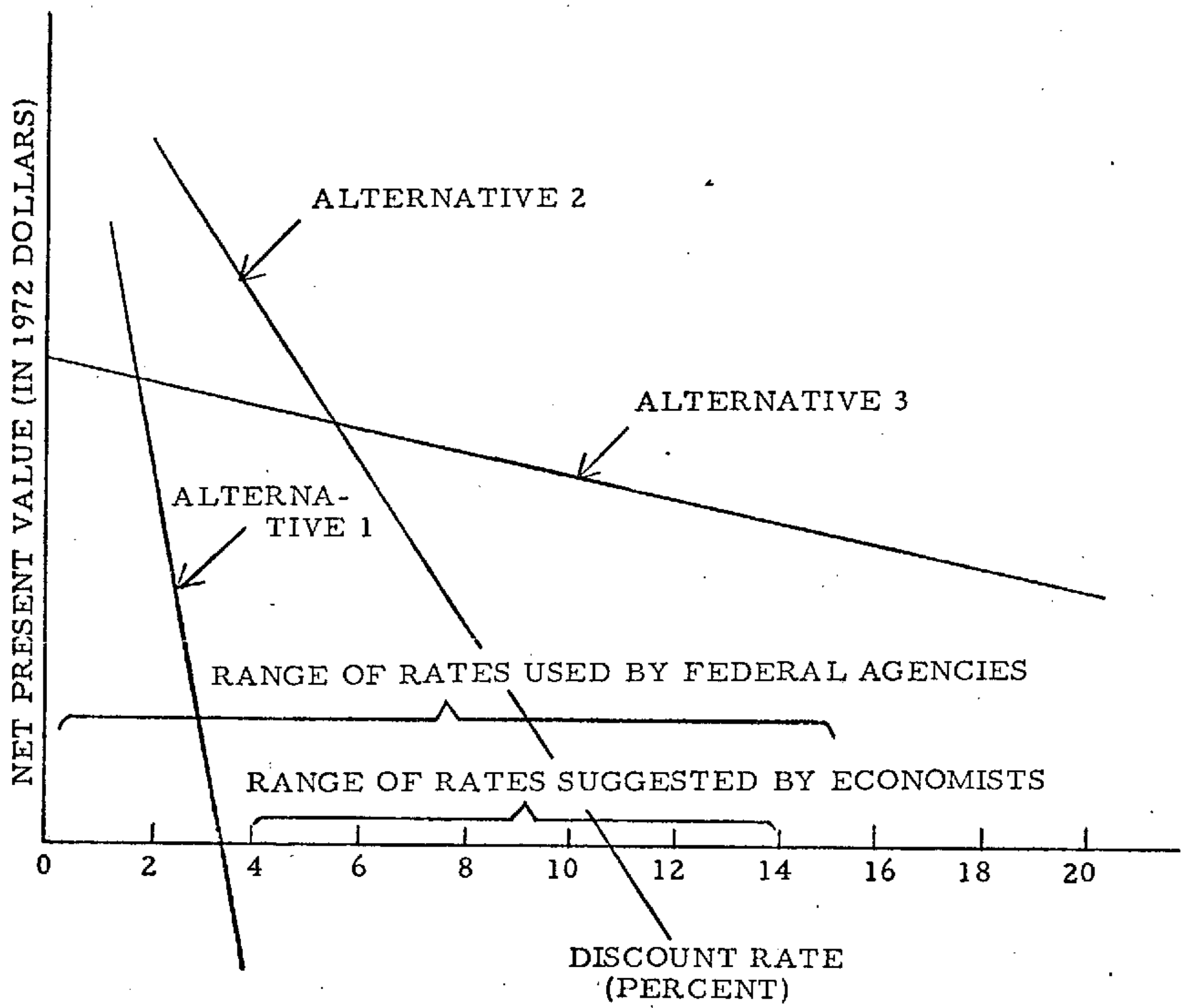


Figure IIA-3. Project Evaluation: Net Present Value as a Function of Discount Rates Used

At some stage of the evaluation of the ERTS-type systems, the range of plausible social discount rates must be sufficiently narrowed to overcome the ambiguities left by the flexible approach. This narrowing of the range of plausible rates, however, cannot proceed on a rational basis unless the arbiter has at least some understanding of the conceptual issues involved in the estimation of the social rate of discount. Only on the basis of such an understanding can a government agency decide or argue that say, 7.5 percent is likely to be a better approximation of the true social rate of discount, than, say, 12 percent.

The effect of the rate of discount on the evaluation of the four investment alternatives may be examined between the ranges of 5 and 15 percent (for all integer numbers). A sample output of one alternative evaluation for one particular case study is shown in Table IIA-2.

C. Risk Analysis

Risk analysis is a means of developing quantitative measures of the uncertainty associated with ventures and providing numerical estimates of the range of probable outcomes.

Variation in costs will arise in ERTS experiments due to the reliability with which cloud cover permits adequate pictures, the satellite functions, the photos are collected processed and distributed, etc. Beside the question of technical reliability of the overall system there is the uncertainty of the costs incurred in all steps of the system over its life.

Table IIA-2. Net Present Value of Alternative 3 Equal Budget Efficiency Calculation

(in millions of 1972 dollars)

STUDY	HORIZON	SYSTEMS	DISCOUNT	NPV COSTSAVINGS	NPV INDUCED BENEFIT	NPV TOTAL
CASE-D	INF.	A3 VS BASE	1	2.867	1.318	4.186
			2	2.417	1.104	3.522
			3	2.045	.928	2.973
			4	1.735	.782	2.518
			5	1.477	.661	2.139
			6	1.261	.560	1.822
			7	1.080	.476	1.557
			8	.928	.406	1.334
			9	.799	.347	1.147
			10	.691	.297	.988
			11	.598	.255	.854
			12	.519	.220	.740
			13	.452	.190	.643
			14	.395	.164	.560
			15	.346	.143	.489
			16	.303	.124	.428
			17	.267	.108	.375
			18	.235	.095	.330
			19	.208	.083	.291
			20	.184	.073	.257

A3 VS BASE = Alternative 3 versus Baseline (No system)

Because of the many areas of uncertainty which influence costs, it is not realistic to consider costs as being well defined, single valued functions. Costs can be described as illustrated in Figure IIA-4 where costs are shown as ranges of possible values with different probabilities of falling into various parts of the range. And because annual cost is a function of probabilistic costs, it too will have a probability distribution.

The annual costs are derived using the previously developed costing model, collecting inputs as probability distributions by "off-the-cuff" estimates of experts or by the Delphi technique [25], and performing simulation.

The simulation uses Monte-Carlo* techniques to establish the probability distributions (risk profiles) of the different events, their annual costs and total cost.

The simulation iteration works as follows:

(i) First, a number for each of the input factors in the system cost model is obtained by "sampling" from their respective probability distribution for each year of the project.

(ii) Next the system cost model is used to calculate the total cost. This constitutes one simulation.

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*Monte-Carlo implies the repetition of a modeled experiment, sequence of events, physical process, etc., whose component outcomes are probabilistic, a sufficient number of times to generate a "smooth" profile or histogram of all possible outcomes. This resulting profile of predicted outcomes for the model is then normalized to a relative frequency profile which represents the probability density function for the experiment's outcome.

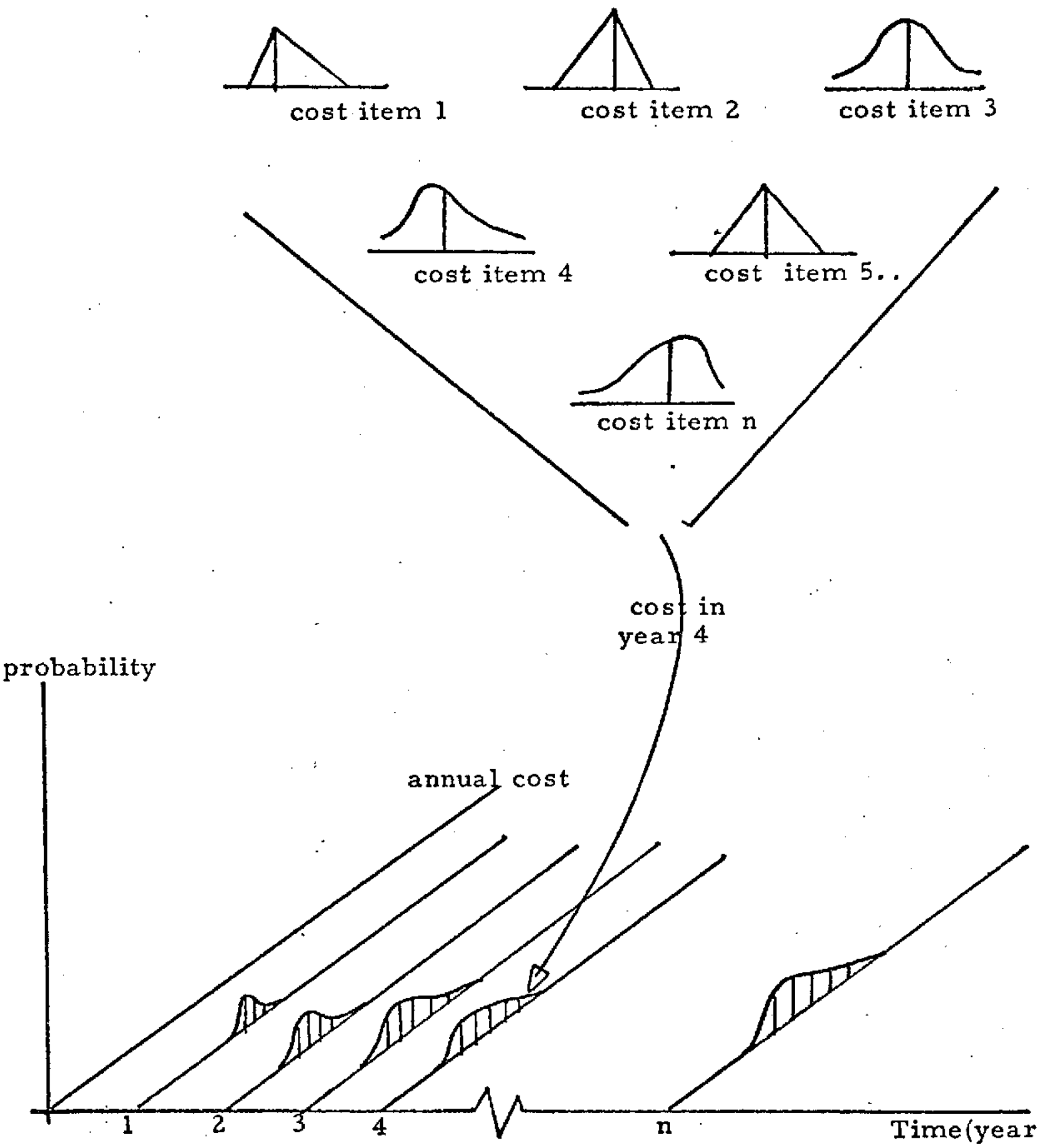


Figure IIA-4. Probability Density Functions for a Stream of Uncertain Costs

(iii) The process outlined in (i) and (ii) is repeated a large number of times (say 1000) and the results tabulated in the form of histograms. See Figure IIA-5 for an example.

(iv) Finally, these histograms are printed together with summary statistics in the form of reports which are useful to the analyst.

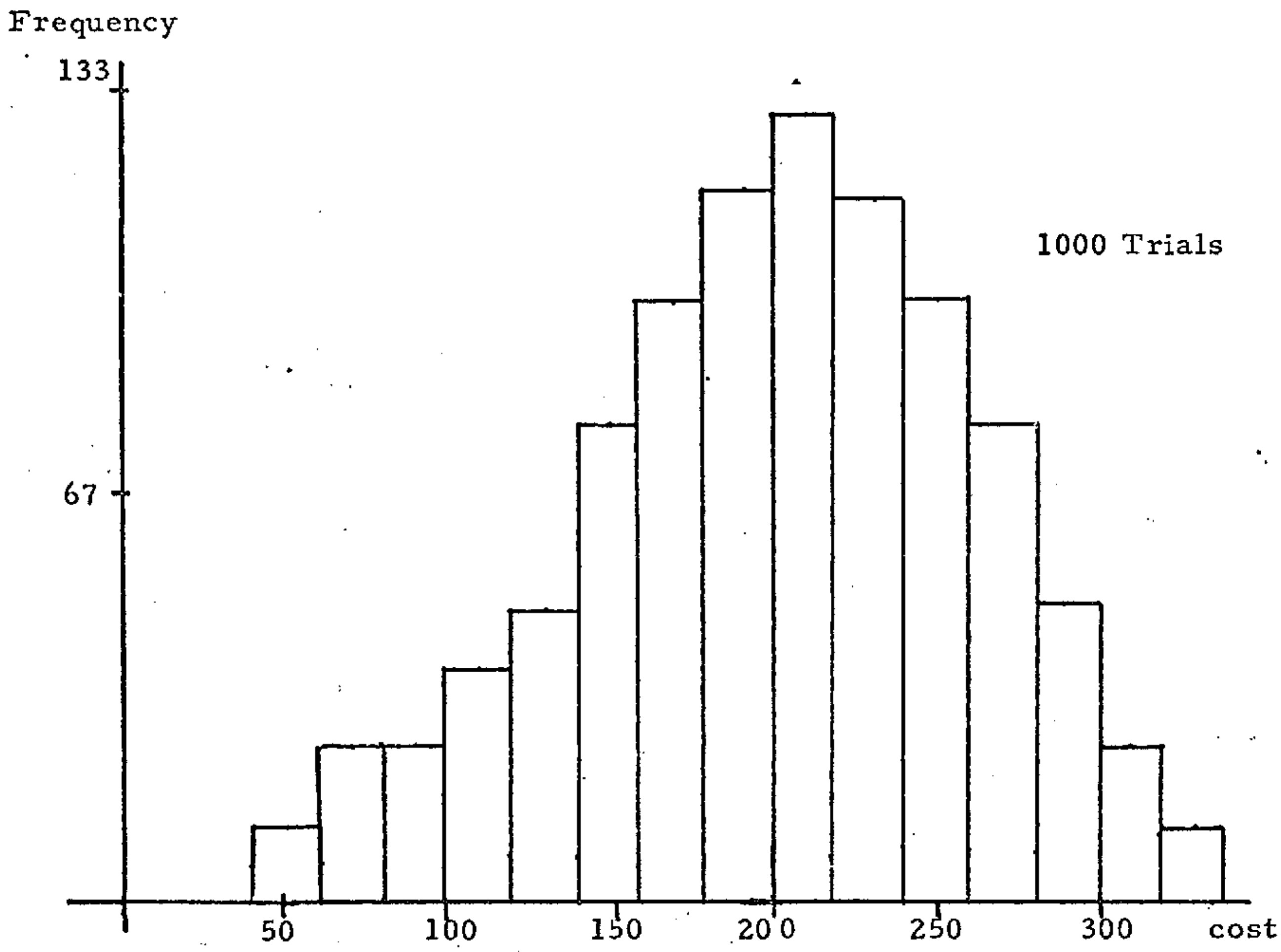
The overall procedure in risk analysis is outlined in Figure IIA-6. While this section has spoken only of the cost model, the same risk analysis can be applied in those cases where benefits are quantifiable and uncertainties exist.

Having the total cost estimate of a system as a probability distribution function rather than a single value estimate enables the decision maker to attach some measure of certainty to his choice.

Chance variation in the input variables is usually allowed for by sensitivity analysis. But sensitivity analysis asks only over what range the original policy choice holds when just one of the input variables is permitted to vary. Nor does it permit statements of probability.

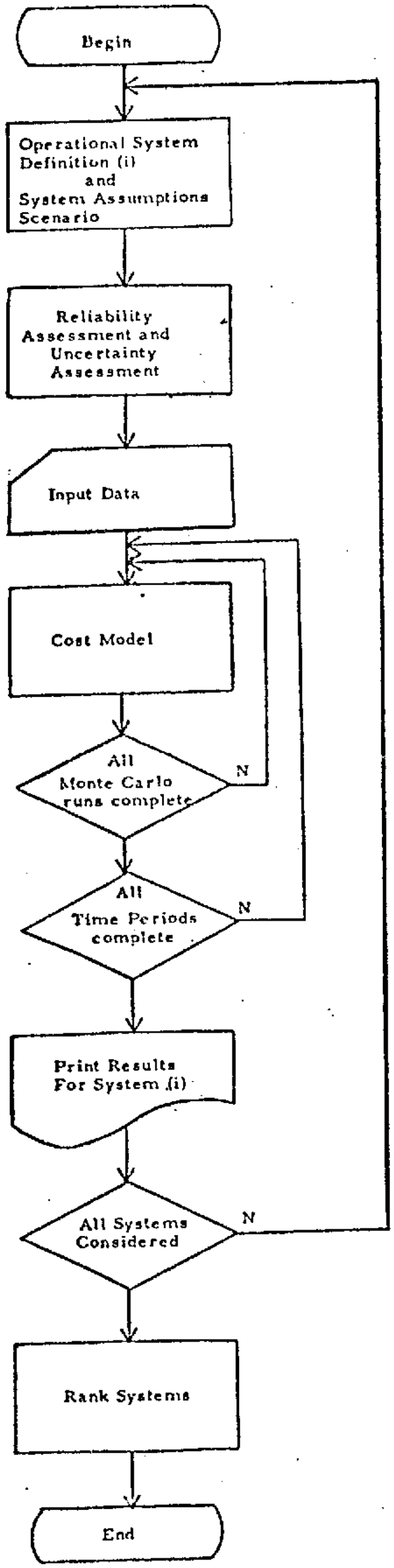
Further, a deterministic model implies an optimal decision can be correctly made each time the appropriate data are collected. But, in fact, the empirically given problem permits incorrect decisions even when the appropriate data are available and collected properly. This is because many of the variables are estimates with random errors rather than "knows."

Figure IIA-5. Results of ERTS Experiment
Total Cost Simulations



Summary of Statistics (in Million $)
Mean Value 192
Standard Deviation 54

Figure IIA-6 Risk Analysis Procedure



More realistic and more powerful statements and decisions can be made if the cost model is used with probabilistic variables. This procedure is also more consistent with the manner in which input data will be collected.

The following example illustrates how sensitive total cost estimates are to variation in the input data.

In an earlier paper by MATHEMATICA [47] the following hypothetical analysis was conducted.

Four systems were considered for a survey to detect strip mining violations:

P_1 = Ground (men) only

P_2 = Satellite + Ground

P_3 = Aircraft + Ground

P_4 = Satellite + Aircraft + Ground

Systems P_2 and P_3 were found to be most efficient with the cost of survey (in $1,000) for

$P_2 = 36.6$

$P_3 = 34.5$

But these estimates depended to a great extent on our ability to make proper decisions from aircraft or satellite photos. We are given

α = probability "good" area is misclassified as a problem area

β = probability a problem area is misclassified as good.

s, a - denote satellite and aircraft respectively

By assuming reasonably small random variation in these two variables, α and β, we can see that there is a one in four chance that an incorrect choice of systems will be made.

Under P_2 we are given the following cost function

$$C_1 = 2,700 + 47,500\ (\alpha_s) + 97,500\ (\beta_s)$$

$$\$36,575 = 2,700 + 47,500\ (.20) + 97,500\ (.25)$$

Under P_3 we are given the following cost function

$$C_2 = 17,500 + 97,500\ (\beta_a) + 47,500\ (\alpha_a)$$

$$\$34,500 = 17,500 + 97,500\ (.15) + 47,500\ (.05)$$

For P_2 let $\hat{\alpha}_s = .20 \pm .02$ and $\hat{\beta}_s = .25 \pm .02$ and both be normally distributed.

Further, let	Then Z, Z_1, Z_2 will be normally distributed with (μ ; σ):
$Z = (C_1 - 2,700)$	(33,875; 1,429)
$Z_1 = 47,500\ \alpha_s$	(9,500; 950)
$Z_2 = 97,500\beta_s$	(24,375; 1,950)

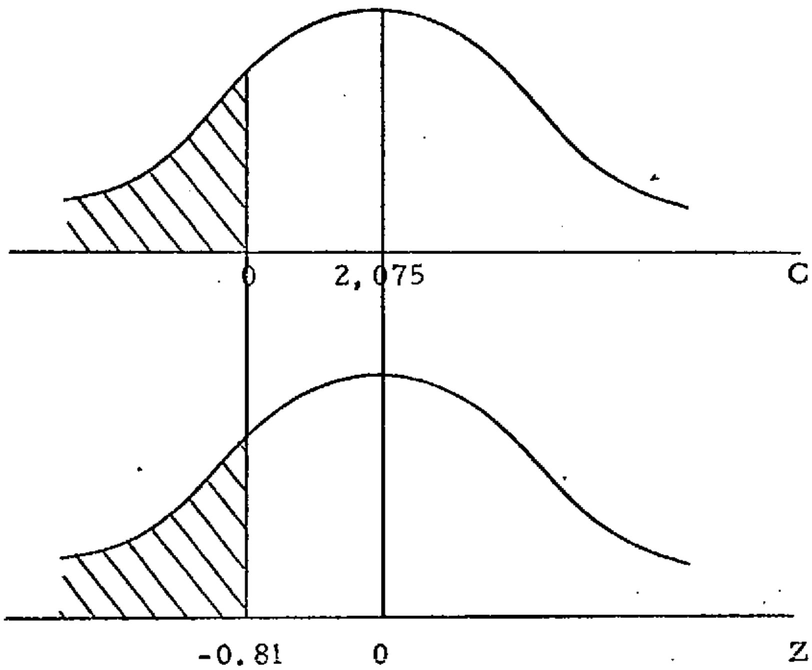
Therefore, $\hat{C}$ is normally distributed with (36,575; 1,429).*

For P_3 let $\hat{\beta}_a = .15 \pm .02$ and $\hat{\alpha}_a = .05 \pm .01$ and both be normally distributed.

Further, let	Then V, V_1, V_2 will be normally distributed with (μ ; σ):
$V = (C_2 - 17,500)$	(17,000; 2,007)
$V_1 = 97,500\ \beta_a$	(14,625; 1,950)
$V_2 = 47,500\ \alpha_a$	(2,375; 475)

*From $\mu = \mu_1 + \mu_2$, $\sigma = (\sigma_1{}^2 + \sigma_2{}^2)^{1/2}$

Therefore, $\hat{C}_2$ is normally distributed with (34,500; 2,007). Finally, $\hat{C} = \hat{C}_1 - \hat{C}_2$ is normally distributed with (2,075; 2,464).



Note: The probability that C_2 is greater than C_1 (i.e., $C < 0$) is .2996 or about 30%.

Conclusion: There is a 70% probability that we will make the correct choice in selecting Policy 3 (Aircraft + Ground) in this case as the more cost effective system.

D. Definition and Measurement of Benefits

Broadly speaking, benefits can be estimated for private groups (individual corporations) or for public decision makers.

Benefits in the context of private entities (corporations, individuals) are usually defined as the net revenues expected to flow from the investment alternatives under consideration. The economic value of these benefits is determined by the market place and conveniently expressed in monetary units.

Benefits in the context of public decision makers do not usually accrue in the form of a monetary revenue stream; instead, a monetary value must typically be imputed indirectly. Examples for such analysis can be found in:

1. Multipurpose River Developments
2. Highway Construction
3. Investment in Health
4. Nuclear Reactor Development Programs
5. Space Transportation System Investments

The measurement of benefits for public investment evaluation is an extremely intricate and challenging problem. We discuss in the following a consistent, and we hope acceptable, approach that has been implemented in practice.

Measurement of Benefits in the Absence of Market Indicators: Cost-Effectiveness and Cost-Benefit Analysis.

In the economic literature, the terms "cost-benefit" and "cost-effectiveness" are sometimes used as equivalent terms. Cost-benefit analysis applies for one alternative system. If there are three alternative systems available for achieving the objective, we apply cost-benefit techniques three times under restrictive assumptions (e.g., equal capability or equal budget) to get a cost-effectiveness analysis. Cost-benefit analysis is also defined as the broader task of selecting a single system from all of the possible cost-effective candidates.

Cost-Effectiveness Analysis of Technical Innovations

A technological innovation such as an ERTS-1 system will change the efficiency frontier for earth resources management. In general, technological change will shift the efficiency frontier, F_0, as shown in Figure IIA-7 upwards and towards the left (see also Figures IIA-8 and IIA-9). If one evaluates an efficient project prior to the introduction of the new technology, e.g., point P_0, (the baseline technology), one sees that P_0 is not any more cost-effective with regard to the new efficiency frontier F_1--and in the absence of the (necessary) non-recurring costs. That is, after technological change and innovation have taken place, we can find, with the new technology, other systems that provide the same capability at less cost (P_1) or more capability at the same budget level (P_2).

Technological change does not always "rain" onto society in a steady stream; the more recent history of technology, especially in space related activities, suggests that technological change must

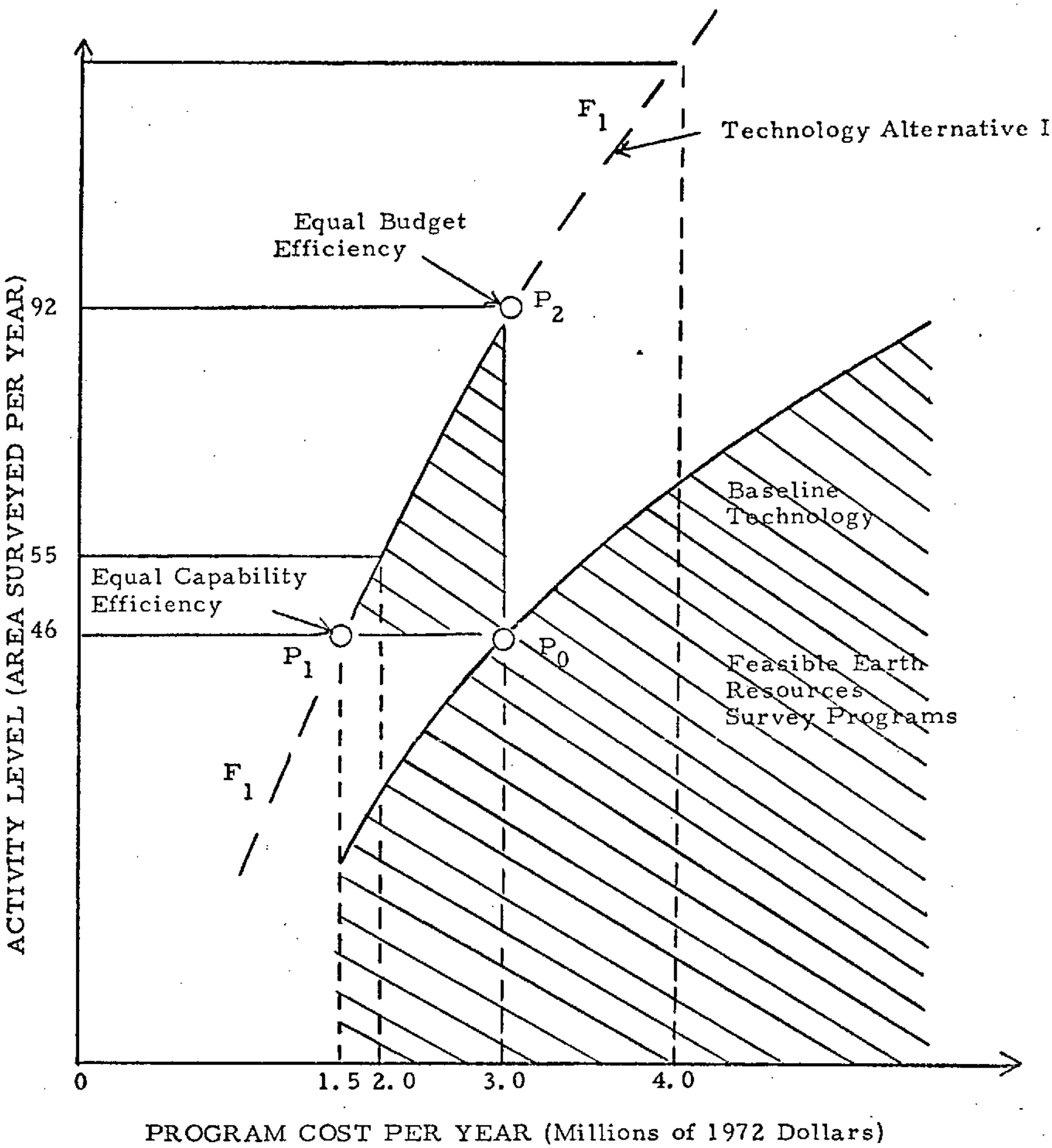


Figure IIA-7. The Scope of Cost Effectiveness Analysis of New Technology Choices commonly be "purchased" by substantial investments in RDT & E and initial investment in new hardware. Suppose now that it is known with a fair degree of certainty that a given RDT & E effort considered separately will be capable of shifting the cost-effectiveness frontier from its present position (e.g., from line F_0 to line F_1 in Figure IIA-7). Within the confines of cost-effectiveness analysis (strictly defined) one may now ask the following questions:

(a) Equal capability efficiency

What is the net cost saving which can be achieved by adopting the new technology, and are these cost savings (i.e., $P_0 - P_1$) large enough to justify the incremental (non-recurring) outlay on RDT & E and new hardware[1], over the uselife of the new system? (Figure IIA-8).

and

(b) Equal budget efficiency

What increases in capability are brought about by technological change, at the same budget level, after the new system has been introduced, and will the economic value of this added capability justify the required, incremental outlays on RDT & E and new hardware over the uselife of the new system? (Figure IIA-9).

Question (a) above is by far the easier one to answer from an empirical point of view. In answering that question, one need only make the assumption that the expenditure on a capability prior to the development

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[1] Excluding those costs which have been "sunk."

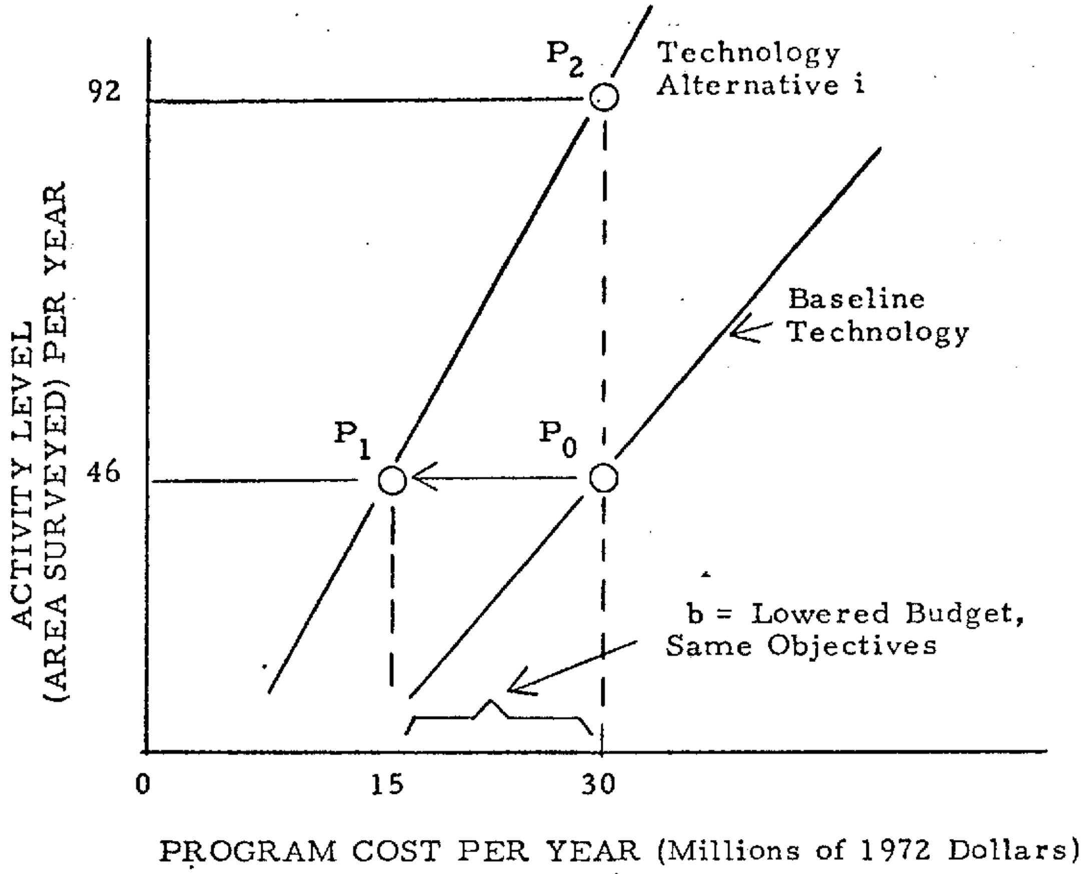

Figure IIA-8. Equal Capability Cost Effectiveness Analysis

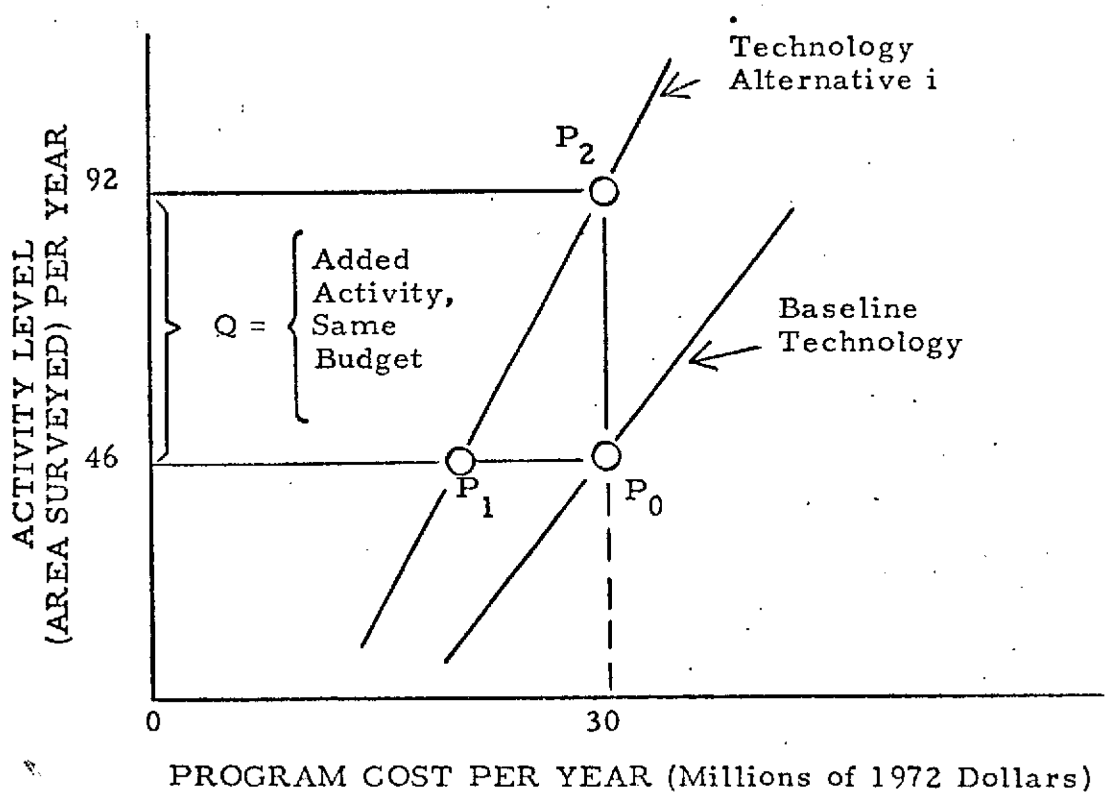

Figure IIA-9. Equal Budget Cost Effectiveness Analysis of the new technology represents the economic value of this capability to society. Based upon this assumption, a very conservative and objective estimate of the benefits from the new technology is the annual cost savings achievable at the activity level purchased under the old technology. If it is found that the total cost saving, aggregated over the uselife of the project and adjusted for the time value of economic resources, more than covers the initial outlays on RDT & E and hardware for the new system, then one may unambiguously conclude that based upon cost effectiveness, the new system should be developed and adopted.

It is much more difficult, in practice, to answer question (b) above. For the question really amounts to asking:

(b') Given the fact that we can increase our capability due to the introduction of a new technology, does the economic value of the added capability justify the required additional expenditures up to an equal budget outlay?

Clearly, this question cannot be answered unless one can, in fact, place a value on the additional capability. In other words, question (b) really requires one to know society's demand curve for the activity in question.

Benefit Measures That Result From Cost-Effectiveness Analyses

Given the two limiting ranges of cost-effectiveness analysis (equal capability and equal budget) the benefits attributed to the investment alternatives when compared to the Baseline technology are shown in Figure IIA-10. The Equal Capability Benefits are simply the estimated cost reductions expected from the use of alternative technology choices. The Equal Budget Benefits are augmented by the area under the Equal Budget Demand Curve, and the marginal costs of the technology alternative (MCI) for the increased activity level.

Once we are involved in the placing of economic values, a further extension of cost-effectiveness analysis is suggested, i.e., benefit-cost analysis. In principle, at least, there is no reason why question (b') above should be confined to a unique budget outlay. One might just as legitimately ask whether the economic value of any additional capability justifies an expansion of the budget required to achieve it. That is, any addition to expenditures (budget) may be justified so long as the economic benefits associated with the incremental capability at least offset the incremental expenditure.

It is obvious, then, that cost-effectiveness analysis in the narrow sense of that term as defined above has at least one severe shortcoming: the approach abstracts entirely from the pertinent question whether or not marginal changes in project scale (i.e., in the proposed budget level or in the proposed effectiveness level) are economically desirable. A fundamental theme of our argument is therefore that cost-effectiveness alone -- either question (a) or (b) -- constitutes a simplified view of the problem.

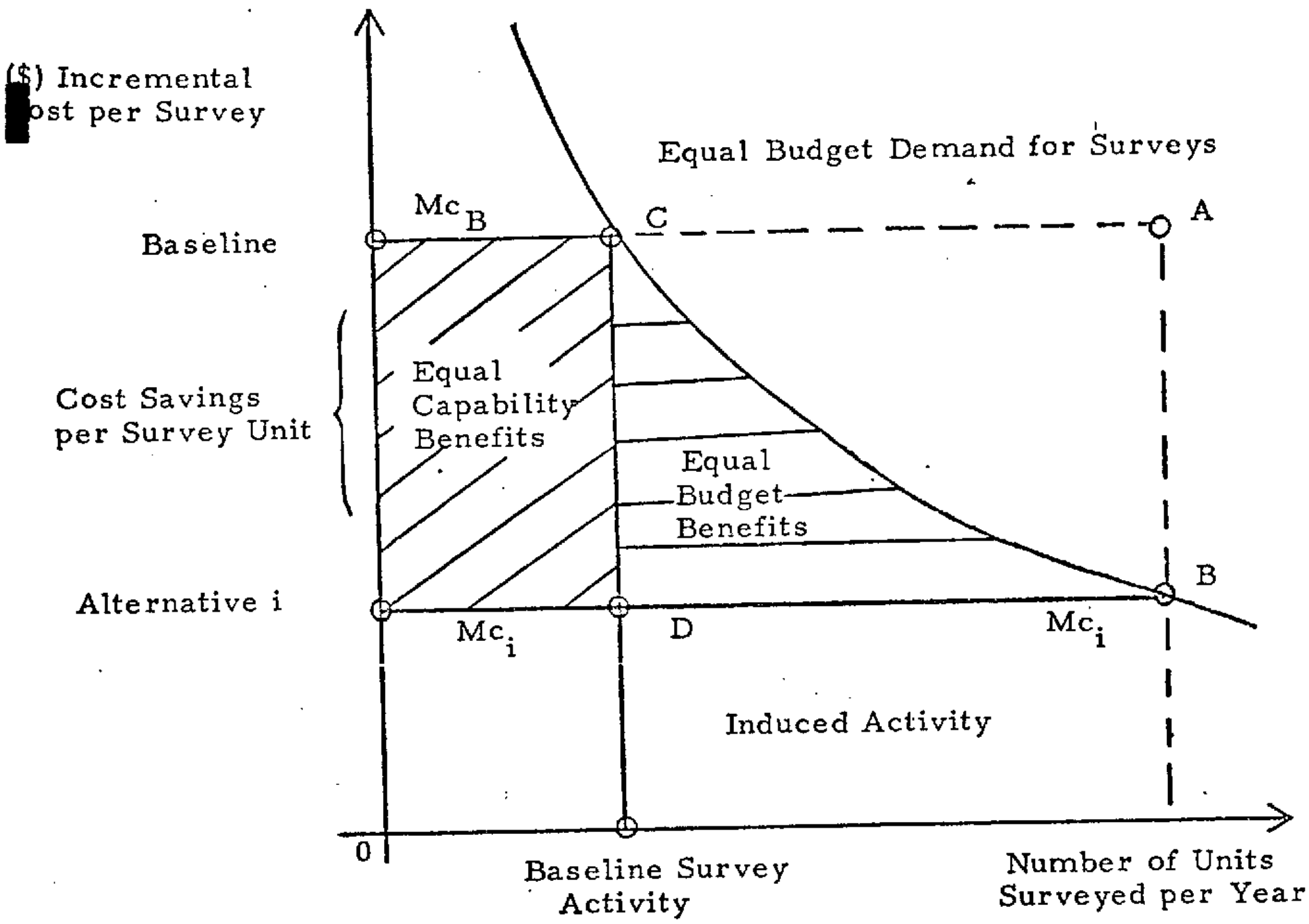

Figure IIA-10. Benefit Measures Resulting from Cost-Effectiveness Analysis

The Direct Measurement of Benefits (When Market Indicators are Present)

The previous section discusses alternative approaches for a benefit-cost analysis of data from ERTS-1 earth resources observation systems when the information gathered is used for providing public goods. This is typically the case when the users of information belong to the public sector. The values of services or goods they provide cannot be determined by the market prices, since they are usually free or charged only with a token fee. It is expected that the information gathered from ERTS-1 type earth resources observation systems can be useful not only to the public sector but also private sector. This information may be provided to the private sector with or without charging the fees. The pricing policy actually adopted will undoubtedly affect the cost and supply of producing consumer goods, since the information is used as an input. The problems of optimum pricing and resources allocation have been examined elsewhere [2]. The following discussion will be based on the assumption that the pricing policy has been settled, and the costs of information to the private producers of final consumption goods are known. Therefore, the introduction of ERTS-1 type earth resources observation systems can be treated simply as a shift of supply curve of the final consumption goods.

How critically important such considerations are for the economic and social benefit evaluation of projects was illustrated by the movement of wheat prices in the summer of 1972.

Furthermore, we shall assume that the supply curve, which also reflects the industry marginal cost curve, is sloping upward, i.e., decreasing returns to scale. On the other hand, the demand curve is assumed to be sloping downward. Based on these basic assumptions, we shall analyze how the market equilibrium of a final consumption goods, e.g., agricultural products, which is likely to be affected by the ERTS-1 type earth resources observation systems may be expected to change. More importantly, we shall attempt to sketch a framework which may be useful in evaluating the economic value of an ERTS-1 type earth resources observation system to any private industry. The analytical framework is very general and is similar to what we have employed for evaluating the economic value of information for the public sector producing public goods. The main differences between the analyses of this and the previous section rest on the fact that the demand curve can now be estimated from the observations on consumer's behavior (instead of government budgetary decision) and that the supply curve (or marginal cost curve) reflects the behavior of the firms (not merely the technical feasibility).

Without discussing the details of the short-run versus long-run and micro versus macro, we shall somewhat arbitrarily assume that we are interested only at the macro (or more appropriately, industry) level for a short-run equilibrium situation. Furthermore, we shall assume the Marshallian partial equilibrium (despite its possible theoretical weakness) will be adequate so that a full Walrasian equilibrium approach will not be necessary. This is justifiable mainly on practical grounds. With these assumptions, our discussion of welfare implications will rely mainly on the concepts of consumer's surplus and producer's surplus. This is done even though we realize that these concepts may have their limitations.

The Nature of Technological Progress in a Market Economy

Most theoretical and empirical studies of technological progress in a market economy have been limited to macroeconomic analyses. While the theoretical discussions are largely related to various growth models, such as Harrod-Domar model, the empirical investigations are largely associated with Cobb-Douglas or Constant Elasticity of Substitution (CES) Production Functions.

In general, technological progress can be regarded as either embodied or disembodied into the capital or labor. Although embodied models may be more satisfactory theoretically, disembodied models are by far much easier to implement (and have been used empirically with some success). Furthermore, technological progress can also be labor augmenting (e.g., Harrod-Neutral) capital augmenting (e.g., Solow-Neutral), or both labor and capital augmenting (e.g., Hicks-Neutral). The type of technological progress not only affects how the supply curve is shifted but also determines the distribution of income among the owners of different resources (labor or capital). The issues related to income distribution are obviously important and deserve further investigation. In what follows, our discussion of the welfare implications of technological progress, however, will be limited to its impact on the society as a whole and the distribution of the gain (or loss) between producers and consumers.

Production Technology and Supply Function

As indicated earlier, the economic values of the information gathered by ERTS-1 type earth resources observation systems to the private sector of the economy may be judged from its impact on equilibrium of the market of final consumption goods reached through the price mechanism. For simplicity, we shall consider only one commodity. The Marshallian partial equilibrium approach to be discussed below can be generalized, as was done in Walrasian general equilibrium approach. The substance of the analytical approach can be made clear within the simpler framework. Briefly, the equilibrium values of the quantity and the price of a given market (where a given commodity is exchanged) is determined by the solutions of the supply function and the demand function. We now begin to examine how . technological progress such as the introduction of ERTS-1 type earth observation systems can affect the supply function. In order to do so, it is best to describe how the supply function is usually derived.

Since we are dealing with the private sector of the economy in this section, it is reasonable to assume that all firms and thus the industry as a whole behave in such a way as to maximize total profits under a given technical feasibility constraint. For any given level of the output price, there is a profit maximizing level of quantity which the producers will be willing to supply. The functional relationship representing the feasibility constraint between maximum output for a given input(s) (or minimum input(s) for a given output) is the <u>production function</u>. The functional relationship between the profit maximizing output and the output price is the <u>supply function</u>.

The feasibility constraint or the state of technology for the production of a given commodity may be summarized in the production function as

$$y = f(x_1, x_2 \ldots x_n) \tag{1}$$

where y and $x_1, x_2 \ldots x_n$ represent the quantities of output and inputs respectively. The profits may be expressed as

$$\begin{aligned} \Pi &= R - C \\ &= P(y)y - \Sigma P_i(x_i) \cdot x_1 \end{aligned} \tag{2}$$

where R and C are total revenue and total cost, and P(y) is the inverse demand function of the output y, and $P_i(x_i)$ are the inverse supply functions of the factor inputs. Under the assumption of perfect competition in the output market, $P(y) = \overline{P}$, implying perfectly elastic demands for the outputs of individual firms. Each producer may be supposed to minimize total cost for the production of any given level of output $\overline{y}$. In other words, he is supposed to minimize

$$\Phi = \Sigma P_i(x_i) \cdot x_i - \lambda\left[f(x_1, x_2, \ldots x_n) - \overline{y}\right] \tag{3}$$

Denoting the resulting optimum input combination as x_i^* $(i = 1, 2, \ldots, n)$, the corresponding minimum total cost is simply $C* = \Sigma P_i(x_i^*)x_i^*$. Since this minimum total cost is dependent on a given output level, by varying $\overline{y}$, we shall be able to obtain the total cost function as

$$\begin{aligned} C* &= \Sigma P_i(x_i^*) \cdot x_i^* \\ &= \Sigma P_i\left[x_i^*(\overline{y})\right] \cdot x_i^*(\overline{y}) \\ &= F(\overline{y}) \end{aligned} \tag{4}$$

From (4), the marginal cost function can be derived as

$$MC = \frac{\partial C^*}{\partial \bar{y}} = F'(\bar{y}) = P \tag{5}$$

which is also the supply function of the firm. By summing the supply of all firms at each given level of prices, the industry supply function of a given commodity can be obtained.

So far, we have demonstrated the derivation of the industry supply function for a given commodity based on a given technology or production function. The introduction of the ERTS-1 type earth resources observation systems may be expected to change the technology or production function of a given commodity. Therefore, the resulting industry supply function may also be expected to change. The precise nature of such a change cannot be determined without specific knowledge of the production functions for both the existing technology and the potential new technology. Furthermore, it must be pointed out that it is not unlikely that the new technology which is beneficial to the society as a whole may not always be the most profitable to the private industry. In this case, some form of government intervention may not only be justifiable but also desirable. The problem is important and deserves further investigation.

Before entering the discussion of the demand for final consumption goods, it is worthwhile to mention the derived demand for factor inputs, which may include information obtainable from the ERTS-1 type earth resource observation systems. From the first order of conditions for the minimization of (3) consisting of n + 1 equations, we can derive n factor input demand functions and the value of λ in terms of n factor prices and output level. Consider one of these n factor inputs as information obtainable from ERTS-1 type earth resources observation systems, the value of the information can be estimated from its derived demand function. Similar derived demand functions for the information from the production of all commodities can be summed up vertically to obtain total derived demand for information, treating the information as "collective goods" or "public goods." On the other hand, if the information gathered by the satellite can be treated as private goods, then horizontal summation may be done to obtain total derived demand for information. This latter approach is perhaps less applicable. Once the value of information can be determined through its demand function, the desirability of an information gathering system can be evaluated if in addition the cost function of providing the information is known. In general, alternative derived demand functions may associate with different information gathering systems which usually involve different cost functions. Theoretically, such an approach of evaluating the value of information at the level of factor input market may be more satisfactory. Practically, such an approach is likely to be much more difficult than the alternative of evaluating the value of information at the level of final consumption goods markets. We shall now turn to consider the demand side of a final consumption good.

Consumption Preference and Demand Function

The derivation of the demand function of a final consumption good based on utility maximization subject to a budget constraint is relatively straightforward. Briefly, the consumer is supposed to maximize

$$U = U(x_1, x_2, \ldots x_n) - \mu(\Sigma P_i x_i - \overline{B}) \tag{6}$$

where $U(x_1, x_2, \ldots x_n)$ is his utility function and $\overline{B}$ is a given budget. The demand functions of n commodities and the value of μ are obtained by solving the n + 1 equations of the first order conditions.

The demand function of a commodity which may require information obtainable from the ERTS-1 type observation systems is not supposed to be affected by a change in production technology resulting from the introduction of the ERTS-1 type observation systems. It may, however, be expected to shift because of the population growth or a change in preference or taste, etc. The derivation of the industry demand curve from the individual demand curves is straightforward and thus need not be elaborated. Compared with the estimation of supply function and the assessment of the effect of technological change, the estimation of demand functions for various commodities, such as agricultural products or any other products, is relatively easy. Furthermore, many empirical analyses of demand functions already exist and can be very useful. A review of empirical studies of supply and demand analyses will not be presented.

Technological Change and Market Equilibrium

We have indicated that the market equilibrium is represented by a solution satisfying both the industry demand function and supply function. We have also suggested that the impact of a technological change can be summarized in a change in the supply functions of the relevant commodities. In general, it can be shown that technological progress is beneficial to the society as a whole and to the consumers as a group, though its effect on the producers as a group may be uncertain, if the demand curve is sloping downward to the right and the industry is subjected to decreasing return to scale so that its supply curve is sloping upward to the right. This result is brought about through the lowering of the equilibrium price and the increase of equilibrium quantity.

In the accompanying Figure IIA-11, S_1 and S_2 represent the supply curves associated with the "old" and "new" technology, and D represents the unchanged demand curve of a given commodity, say agricultural product.

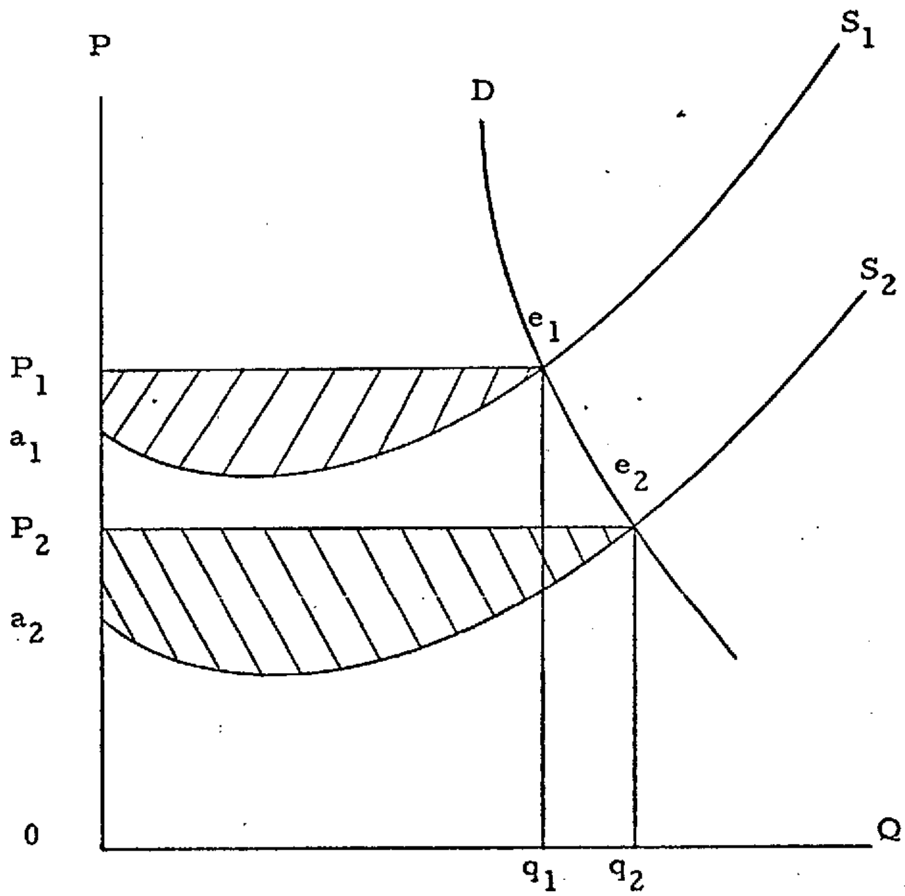

Figure IIA-11. The Impact of Technological Change on Equilibrium Price and Quantity

As is drawn, the equilibrium point moves from e_1 to e_2 as the technological progress is introduced. The figure also shows that the equilibrium price moves down from P_1 to P_2 and the equilibrium quantity moves up from q_1 to q_2. In terms of consumer's surplus, as a result of technological progress, the consumers as a group have gained $P_1e_1e_2P_2$ additional consumer's surplus. The producer's surplus has been changed from the shaded area $P_1e_1a_1$ to the shaded area $P_2e_2a_2$.[1] Whether there is a net gain to the producers as a group is not certain. It is entirely possible that their surplus may be reduced as a result of technological progress. From the society's point of view, taking into account both the consumer's and producer's surpluses, the social welfare has improved by $a_1e_1e_2a_2$ representing the sum of $P_1e_1e_2P_2$ and the net change from $P_1e_1q_1$ to $P_2e_2q_2$.

In the previous discussion, we have implicitly assumed that the form of government intervention, if any, has already been taken into account in constructing the supply and demand curves. In the existence of any government intervention, the cost of this program must also be appropriately taken into consideration. In view of the predominant importance of government intervention in agricultural sectors which is likely to be important to users of the information to be gathered by the ERTS-1 type observation systems, we may now consider the impact of government intervention more explicitly. Since

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[1] More generally, the producer's surpluses before and after technological progress are $P_1e_1q_10$ minus $\int_0^{q_1} S_1(Q)dQ$ and $P_2e_2q_20$ minus $\int_0^{q_2} S_2(Q)dQ$ respectively.

the forms of government intervention are numerous, and the existing literature covers many of the relevant analytical tools, we shall attempt here to consider only a few cases to illustrate how the government intervention may affect the market equilibrium.

In a very general term, in addition to sponsoring research and development, government agencies may intervene in a private market by affecting either the supply curve or demand curve. For example, the government may obtain an agreement from the farmers to limit their land area devoted to the planting of certain agricultural products by granting subsidies. This type of program will effectively shift the supply curve to the left. The government may also enter the market directly as a purchaser or indirectly by subsidizing other purchasers in order to keep the price of an agricultural product at a higher level than otherwise. This type of program will effectively shift the demand curve to the right. In what follows, we shall briefly consider the impact technological progress in the presence of these two types of government programs. We recognize that the actual government programs are much more complicated. The discussion to be presented serves mainly as an illustration.

Referring to Figure IIA-12, the supply curves S_1 and S_2 as well as the demand curve D represent the market supply and demand without government intervention, where S_1 and S_2 represent "old" and "new" technologies. Suppose as a result of government intervention, the land area has been limited and the supply curves become S_1^* and S_2^* instead of S_1 and S_2, the resulting equilibria are e_1^* and e_2^* instead of e_1 and e_2.

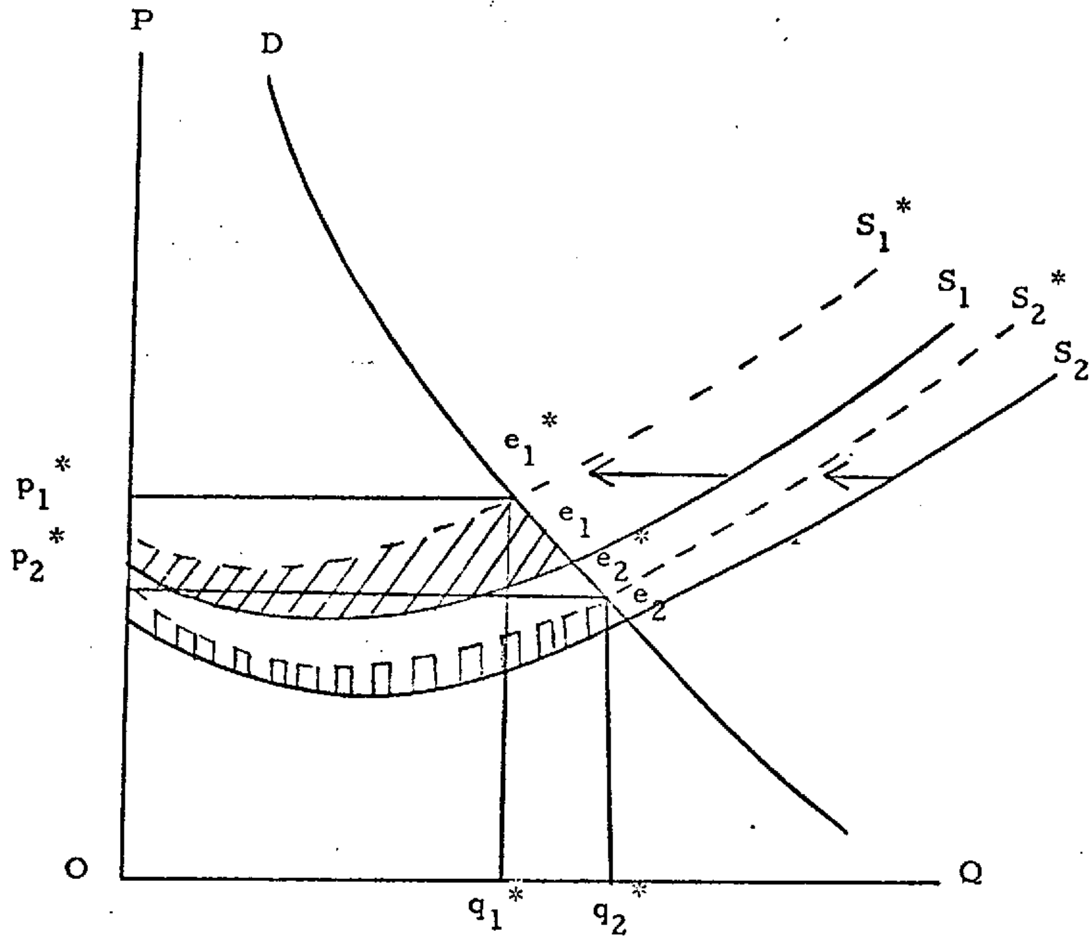


Figure IIA-12. The Impact of Technological Change on Equilibrium Price and Quantity with Government Intervention in Supply Side

The equilibrium prices are higher than those under free market for the corresponding technologies and the equilibrium quantities are smaller. The consumer's surpluses are reduced as a result of government intervention, and the producer's surpluses, excluding government subsidies, are also smaller. For the producers to accept voluntary compliance in restricting their supply, their total profits including government payments of subsidies would have to be larger than what they can obtain from the market without government intervention. The minimum amounts of government subsidies are shown as two shaded areas for the two alternative technologies in Figure IIA-12.

On the other hand, if the government intervenes by adopting a policy of price support, the effect of the program may effectively shift the demand curve to the right. For example, the government may decide to purchase excess supply at a fixed higher price level than what may prevail under free market conditions. Referring to Figure IIA-13, S_2 and D all have the same meaning as before, and D* may be termed effective demand, incorporating the purchases made by the government (with a given amount of subsidies). The amount of subsidy is represented by two equal rectangular shaded areas in Figure IIA-13.

In general, the equilibrium prices under both intervention conditions are higher than the corresponding free market prices. The equilibrium quantity demanded by the private consumers directly are decreased as a result of government intervention which causes higher prices. But the quantities of supply are increased compared with otherwise. The technological progress has obviously increased consumer's surplus, but the impact on producers is again uncertain. From the point of view of the society as a whole, technological progress is clearly beneficial regardless of whether government intervenes in the market or not. Whether government should intervene or not must be based mainly on other considerations.

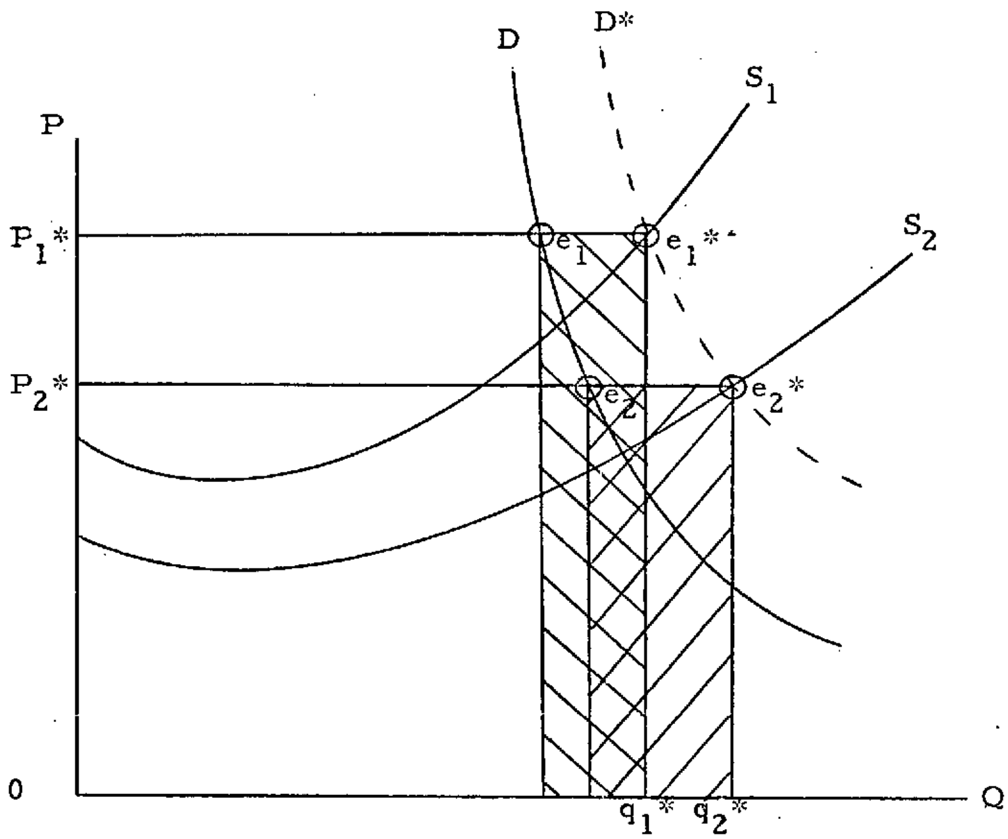


Figure IIA-13. The Impact of Technological Change on Equilibrium Price and Quantity with Government Intervention on Demand Side

E. Externalities

Free market prices provide an efficient allocation of scarce resources in the economy. The pricing process determines who gets resources and output, what output is produced with the resources, and how the resources are combined to produce the output. The prices paid resources also provide the means to allocate the output or benefits.

However, there is a class of benefits (and costs) for which the pricing mechanism breaks down. These anomalous benefits (and costs) are known as externalities.

Externalities are effects produced by individuals or groups for which they can receive no compensation when beneficial to others and for which they cannot be easily charged when costly to others.

The market can fail in two ways when faced with externalities. It can fail to supply (or supply an insufficient quantity) a product or service when the externalities are beneficial effects, e.g., it does not pay private firms to build roads for commercial profit because there is no practical way to collect fees from those who use the roads. The second way the market can fail is to allow a product or good to be supplied (or to be supplied in great quantity) when the externalities are undesirable effects, e.g., a firm may market a product whose production generates such air pollution that if the firm could be charged for the cost of the damage done by the pollution, the product would not be produced.

Situations in which externalities are present are not hopeless, however. For it is here that the government plays an important role. The government is in the position to supply those products with beneficial externalities and to charge (by taxation; see Baumol-Oates technique [48]) for undesirable externalities.

In an earlier paper [2] MATHEMATICA dealt with externalities rigorously. Here it is our purpose to relate externalities to the ERTS experiments.

Externalities are important to ERTS experiments because many of the benefits of ERTS are in the area of resource management and typically take the form of externalities - benefits to society as a whole such as pollution control, weather forecasting, water resource management, etc., for which the market mechanism does not function optimally.

A look at U.S. Government budget outlays for resource management functions should indicate implicitly where the government sees the greatest beneficial externalities. Table IIA-3 breaks down by government agency and organization the estimated outlays for fiscal 1973 for seventeen resource management functions. Table IIA-4 gives the level of spending by function for each year from 1965 to 1973. And Table IIA-5 contains the average annual increase in outlays by function for the years 1965 to 1973. All figures are from [53] , [54] .

These tables give an overall picture of where and to what extent the government is involved in providing services and goods in the area of resource management which the market mechanism does not provide to the public. It is in this framework that ERTS experiments may generate government activity benefits by providing already existing goods and services more cheaply and by providing totally new goods and services.

Table IIA-3

U.S. GOVERNMENT BUDGET OUTLAYS RELATED TO RESOURCE & ENVIRONMENTAL MANAGEMENT BY FUNCTION AND AGENCY (MILLIONS OF $)

(FY 1973 ESTIMATES)

AGENCY/ORGANIZATION

AGGREGATED RESOURCE MANAGEMENT FUNCTION		Department of Agriculture								Dept. of Commerce					HUD		Department of Interior												DoT			Presidential Funds					Independent Agencies				
	Total	Agricultural Research Service	Animal, Plant & Health Service	Commodity Credit Corp.	Statistical Reporting Service	Economic Research Service	Soil Conservation Service	Agr. Stabilization & Conservation Ser.	Forest Service	Social & Economic Statistics Admin.	Economic Development Admin.	Regional Action Planning Comm.	NOAA	Department of Defense - Civil Corps of Engineers	Community Planning	Community Development	Bureau of Land Management	Bureau of Indian Affairs	Bureau of Outdoor Recreation	Geological Survey	Bureau of Mines	Bureau of Sport, Fisheries & Wildlife	National Park Service	Bureau of Reclamation	Power Administrations	Office of Water Resources Research	Department of State - International Boundary and Water Commission	International Fisheries Commission	Planning, Research & Development	Coast Guard	Federal Highway Administration	Appalachian Regional Development Program	Disaster Relief	International Development Assistance	OEO	OEP	EPA	Federal Power Commission	National Science Foundation	TVA	Water Resources Council
354 Agricultural Land and Water Resources	388						189																																		
355 Research and other Agricultural Services	915	204	102		22	17																																			
401 Water Resources and Power	3207																							490		14	21											23		507	7
402 Land Management	918								656								216																								
403 Mineral Resources	103																																								
404 Pollution Control and Abatement	1541																																				1541				
405 Recreational Resources	640																		253			156	224																		
409 Other Natural Resource Programs	176																			145								3													
502 Water Transportation	1225																													756											
503 Ground Transportation	5720																														4917										
506 Advancement of Business	642									61			355																31												
507 Area and Regional Development	8[illegible]7										216	34						76														292									
551 Community Planning, Management and Development	3009														106	2395																			770						
552 Economic and Financial Assistance	2495																																	1455		9					
606 General Science	59[illegible]																																						595		
703 Social and Individual Services	297																																100								
351 Farm Income Stabilization	5011																																								

Table IIA-4

U. S. GOVERNMENT BUDGET OUTLAYS RELATED TO RESOURCE AND ENVIRONMENT MANAGEMENT BY FUNCTION (Million $)

	Aggregated Resources Management Function	1965	1966	1967	1968	1969	1970	1971	1972*	1973*
354	Agricultural Land and Water Resources	342	347	353	351	343	344	346	375	388
355	Research and Other Agricultural Services	483	528	567	615	642	730	813	901	915
401	Water Resources and Power	1761	1940	2025	2069	2041	1983	2389	3005	3207
402	Land Management	509	556	618	639	643	754	837	935	918
403	Mineral Resources	59	62	73	85	71	94	130	121	103
404	Pollution Control and Abatement	134	158	190	249	303	350	701	1287	1541
405	Recreational Resources	215	241	285	331	372	370	479	642	640
409	Other Natural Resource Programs	79	90	93	102	107	122	136	149	176
502	Water Transportation	728	708	765	844	864	902	1041	1200	1225
503	Ground Transportation	4092	4043	4093	4367	4413	4632	5070	5412	5720
506	Advancement of Business	405	351	332	447	152	487	738	744	642
507	Area and Regional Development	557	315	318	472	584	590	717	816	857
551	Community Planning Management and Development	460	721	1023	1277	1509	2171	2486	2745	3009
152	Economic and Financial Assistance	2041	2329	3057	3053	2420	2231	1807	2376	2495
606	General Science	309	368	415	449	490	464	522	538	596
703	Social and Individual Services	249	410	692	831	888	1331	1617	2477	2297
351	Farm Income Stabilization	3667	2536	3167	4542	5000	4589	3651	5501	5011

*Estimate

Table IIA-5

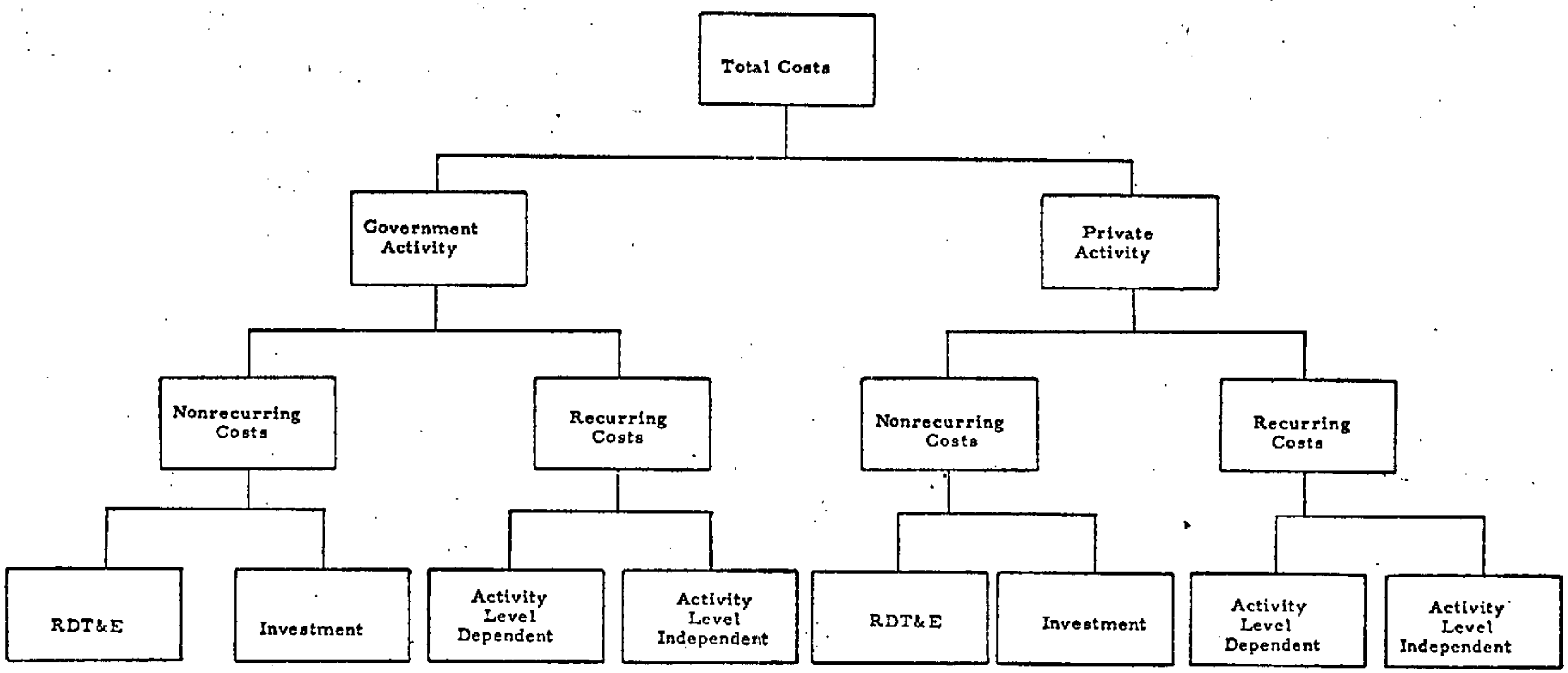
Increases in U.S. Government Budget Outlays

1965-1973

Resource Management Function	Average Annual Increase
Pollution Control and Abatement	31.0%
Social and Individual Services	23.3
Community Planning Management and Development	19.6
Recreational Resources	14.0
Advancement of Business	10.4
Area and Regional Development	10.4
Other Natural Resources Programs	9.5
Mineral Resources	8.9
Research and Other Agricultural Services	8.4
Land Management	7.8
Water Transportation	7.4
Water Resources and Power	7.1
General Science	6.8
Farm Income Stabilization	6.1
Ground Transportation	4.6
Agricultural Land and Water Resources	1.2
Economic and Financial Assistance	-0.9

APPENDIX III

COST FORMS



ORGANIZATION OF LIFE CYCLE COST ANALYSIS

TABLE IIIA-1

COSTS-GOVERNMENT ACTIVITY

SYSTEM ALTERNATIVE ________

Fiscal Year	Non-Recurring		Recurring		Annual Costs
	RDT&E	Investment	Activity Level Dependent	Activity Level Independent	
1973					
1974					
1975					
1976					
1977					
1978					
1979					
1980					
1981					
1982					
1983					
1984					
1985					
1986					
1987					
1988					
1989					
1990					
1991					
1992					
Totals					

TABLE IIIA-2

COSTS-PRIVATE ACTIVITY

SYSTEM ALTERNATIVE ________

Fiscal Year	Non-Recurring		Recurring		Annual Costs
	RDT&E	Investment	Activity Level Dependent	Activity Level Independent	
1973					
1974					
1975					
1976					
1977					
1978					
1979					
1980					
1981					
1982					
1983					
1984					
1985					
1986					
1987					
1988					
1989					
1990					
1991					
1992					
Totals					

TABLE IIIA-3

TOTAL COSTS

SYSTEM ALTERNATIVE ________

Fiscal Year	Government Activity	Private Activity	Annual Costs Undiscounted	Discount Factor*	Annual Costs Discounted
1973					
1974					
1975					
1976					
1977					
1978					
1979					
1980					
1981					
1982					
1983					
1984					
1985					
1986					
1987					
1988					
1989					
1990					
1991					
1992					
Totals					

*See next page.

DISCOUNT FACTORS at 10% Rate

Project Year	Discount factors*	Discount factors**
1	0.909091	0.954
2	0.826446	0.867
3	0.751315	0.788
4	0.683013	0.717
5	0.620921	0.652
6	0.564474	0.592
7	0.513158	0.538
8	0.466507	0.489
9	0.424098	0.445
10	0.385543	0.405
11	0.350494	0.368
12	0.318631	0.334
13	0.289664	0.304
14	0.263331	0.276
15	0.239392	0.251
16	0.217629	0.228
17	0.197845	0.208
18	0.179859	0.189
19	0.163508	0.172
20	0.148644	0.156
21	0.135131	0.142
22	0.122846	0.129
23	0.111678	0.117
24	0.101526	0.107
25	0.092296	0.097

*The discount factors in this column implicitly assume end-of-year lump-sum costs and returns. When costs and returns occur in a steady stream, applying mid-year discount factors may be more appropriate.

**The discount factors in this column implicitly assume a steady stream of costs and returns.

The selection of these discount factors is discussed in section 2.6.3.e of Volume I.

Appendix IV. FORM FOR ENUMERATION OF BENEFITS

The following form gives examples of the type of questions which should be answered regarding the benefits realized by a particular ERTS application. The list should be exhaustive of the non-quantifiable benefits as well as the quantifiable benefits.

The experimenter should check whether the benefit is

1. Domestic and/or international
2. Government oriented or private
3. Quantifiable or non-quantifiable
4. Possible, likely or certain that it will be realized
5. Partially, almost fully, or fully realized
6. An efficiency or non-efficiency consideration

Where the benefit is quantifiable an attempt should be made to distinguish each of these elements in the model and the benefit estimate should be derived by parametric analysis, especially with regard to the extent to which the benefit is expected to be realized.

Form A

Enumeration of Benefits

Form of Benefit	Domestic	International	Government	Private	Quantifiable	Non-Quantifiable	Probability that benefit will be realized			Extent to which benefit was realized			Efficiency Consideration	Non-Efficiency Consideration (Secondary Effect)
							Possible	Likely	Certain	Partially	Almost Fully	Fully		
1.														
2.														
3.														
.														
.														
.														

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